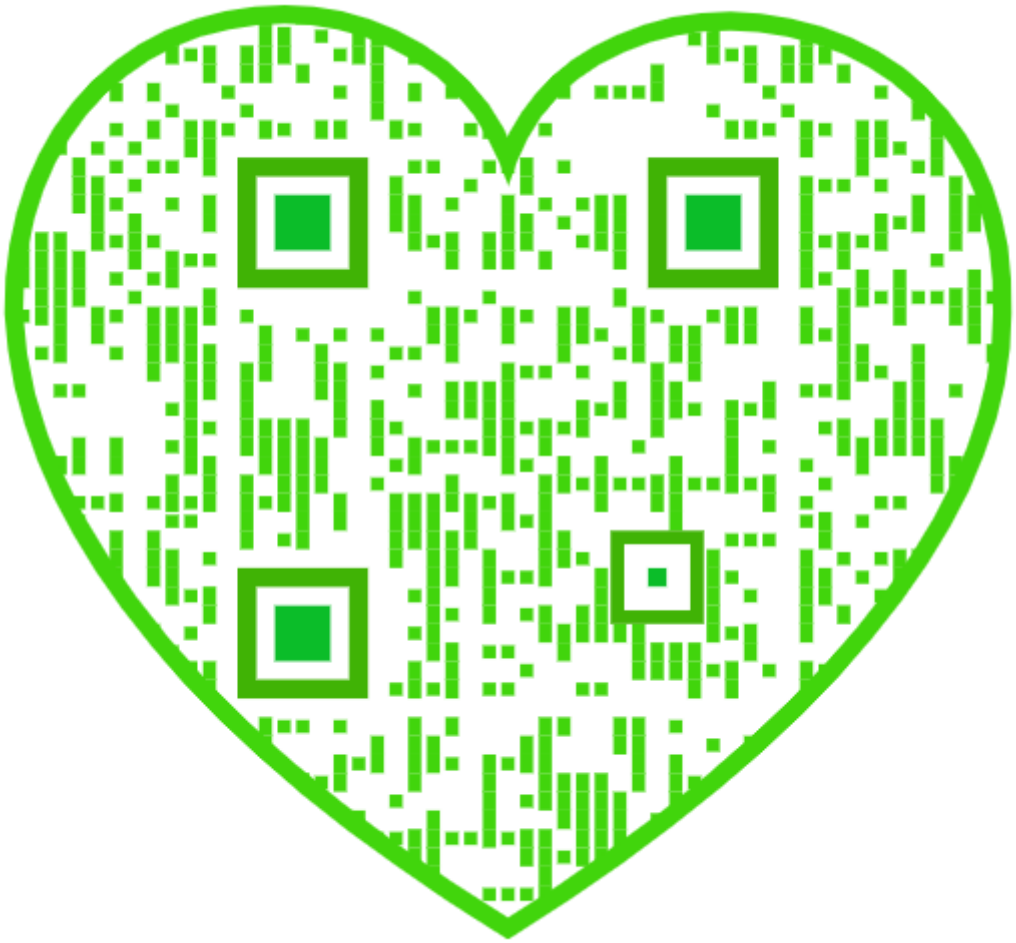

A

# PRACTICAL MANUAL

OF

# OXY-ACETYLENE WELDING

AND

# CUTTING

WITH A TREATISE ON ACETYLENE AND OXYGEN

By P. F. WILLIS

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# PREFACE

Some ten years ago, the author started a welding shop, using the oxy-acetylene process. He hardly knew how to light the torch, much less its operation. In this respect he was on an equal footing with a few other venturesome individuals in this country who had embarked in the same business, regarding which practically nothing was known. It follows that there were many failures and disappointments.

The author can well testify that "there is no royal road to learning," and yet in offering this treatise he is prompted by the belief that the man who goes ahead may smooth out some of the rough spots, and thereby assist those who come after. The book is sold at a price which precludes the possibility of profit to the author. You pay only for the printing and the paper—the subject-matter is gratis. Do not look a gift horse in the mouth too closely.

P. F. WILLIS.

St. Louis, Mo.,
January, 1917.

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# OXY-ACETYLENE WELDING AND CUTTING.

## CHAPTER I.

### ACETYLENE.

*What is Acetylene?*

A hydro carbon gas composed of equal volumes of carbon and hydrogen. By weight it is composed of 93% carbon and 7% hydrogen.

*When was it discovered?*

In 1836 by Davy, an English chemist, and Berzelius, a Swiss chemist.

*From what is Acetylene obtained?*

From calcium carbide.

*What is Calcium Carbide?*

It is a substance, hard like rock, of a grayish color, and possessing a slight crystalline structure.

*When was it discovered?*

In 1892 by an American chemist, named Willson, at Spray, N. C.

*How is it manufactured?*

Lime and coke in the proportion of 56 parts by weight of the former to 36 parts of the latter are fused or melted together in an electric furnace. It is cooled and

crushed, and then assorted as to size by means of screens.

*How is Acetylene obtained from Calcium Carbide?*

When calcium carbide and water are brought together, acetylene is formed. This is accomplished as follows:

The calcium in the calcium carbide combines with some of the oxygen in the water and forms first calcium oxide or quick lime, and then calcium hydroxide (slacked lime). The carbon in the calcium carbide combines with some hydrogen from the water to form acetylene, the chemical symbol of which is $C_2 H_2$.

*Is there more than one method of bringing the Carbide and water together?*

Yes, there are three methods.

*Name them.*

First, water to carbide; second, recession; third, carbide to water.

*Explain each method.*

The "water to carbide" method consists in allowing water, drop by drop, to fall upon a body of carbide. This was the earliest method of generating acetylene and its adoption was due to the fact that it was easier to control the flow of water than it was the feeding of the carbide;

especially as the carbide first put on the market was not uniform as to size.

The "recession" method consists in allowing water to rise, coming in contact with either a mass of carbide or successive layers of carbide.

The "carbide to water" method consists in feeding the carbide in small amounts into a large volume of water.

*Which is the best?*

The "carbide to water."

*Why?*

After generation is impossible and purer gas is produced. Again when carbide and water are brought together heat is evolved.

Now this heat can be considerable, sometimes reaching 1000° F., or it can be negligible, depending entirely upon the amount of water. If there is a sufficient amount of water both the carbide and the water will be kept cool. It has been found that if for each pound of carbide, one gallon of water is supplied, the temperature is kept down—in fact, cannot possibly exceed 212° F., and in practice never goes that high. The "carbide to water" method is the only one that guarantees a sufficient amount of water to assure cool generation.

*What effect does heat have on Acetylene during generation?*

If the heat should rise high enough, what chemists term *polymerization* takes place. By this is meant that the acetylene undergoes a change and is transformed into other gases, such as benzol, styrolene, etc. These latter gases require for their combustion a different amount of oxygen than does acetylene, and their flame temperature is not so high.

A temperature that would produce polymerization, would also be hazardous, and if there was any mixture of air with the gas, an explosion would likely result.

*Is it possible to explode Acetylene?*

Yes.

*How?*

First, when mixed with air in the proper proportions—3% to 58% of acetylene to the rest air—and in the presence of a spark or flame.

Second, at a pressure of 24 pounds it is possible for it to explode without any air mixture, in the presence of spark or flame.

Third, when compressed *in an ordinary container* to 30 pounds or more it may explode without any air mixture and without a spark or flame. Neither concussion or shock are necessary to produce the explosion. An explosion of this character is

generally attributed to decomposition, although some claim that it is due to impurities in the carbide, such as sulphur and phosphorus forming combinations which ignite spontaneously.

*Is it possible to compress Acetylene to 25 pounds or higher safely?*

Yes.

*How?*

The container is first filled with a porous substance, such as asbestos cement. It is then further filled with an inflammable liquid called acetone. This liquid, acetone, has been found to possess the peculiar quality of dissolving or absorbing 25 times its volume of acetylene at atmospheric pressure and continues to do this for each atmosphere of pressure (15 pounds) it is put under.

While the asbestos cement apparently fills the tank, in reality, on account of its porosity, only 20% of the space in the tank is occupied by the asbestos; acetone to the amount of about 43% of the capacity of the tank is then added. This leaves about 37% of the contents of the tank for acetylene as it is taken up or dissolved by the acetone. This absorbing or dissolving quality of the acetone is so remarkable that it may be well to compare the amount of

acetylene that a tank of one cubic foot capacity would contain under fifteen atmospheres (225 pounds) and the amount the same size tank will contain under the same pressure but with the gas dissolved. In the first instance there will be approxi-

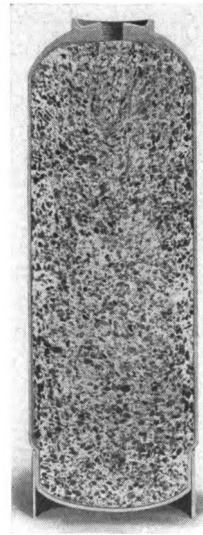

Fig. 1.
Commercial Acetylene Co.'s Tank.

mately fifteen cubic feet of gas. We simply multiply the cubic contents (one foot) by the number of atmospheres (fifteen).

In the latter, however, there will be about

161 cubic feet or roughly estimated at about ten times as much gas as in the first tank. This is obtained as follows:

The amount of acetone is about 43% of the contents of the tank whose capacity was assumed to be one cubic foot. Therefore, the acetone occupies .43 of a cubic foot. At atmospheric pressure the acetylene dissolves twenty-five times its volume of acetylene, so that in this case at zero gauge pressure there is in the tank .43x25 or 10.75 cubic feet of acetylene and at 225 pounds pressure there will be 10.75x15 or 161 cubic feet.

*Does Acetylene exercise a toxic action if air containing a large proportion of it is breathed?*

The best authorities agree that acetylene itself possesses very small poisonous qualities, so that the danger of breathing it is practically nil. This is because it is almost free of carbon monoxide.

*How much Acetylene will a pound of carbide produce when made with a generator?*

Conservatively 4½ cubic feet for the lump size and 4¼ cubic feet for the very small size. One carbide manufacturer claims five cubic feet and another 4.8 cubic feet, but their figures cannot be obtained.

*What is the present price of carbide?*

Three and three-fourth cents per pound without a contract; from 3¼ to 3⅓c per pound with a contract, according to consumption.

*What is the cost of Acetylene per cubic foot made from a generator at above prices for carbide?*

Not to exceed 8/10 of a cent per cubic foot or 80c per 100 cubic feet.

*What is the price of dissolved or compressed Acetylene?*

From $1.80 per 100 cubic feet to large users to $2.15 per 100 cubic feet to the average consumer plus freight on the full tank and on the empty tank returned.

*Taking into consideration the freight, what is the average cost of "tanked" Acetylene?*

Two and one-half cents per cubic foot.

*What size or capacity of Acetylene tank should be used for welding?*

Under no circumstances should a tank of less capacity than 100 cubic feet be used. A tank should not be discharged at a faster rate than one-seventh of its capacity per hour. This means that a welding tip should not be used on a 100-cubic foot tank if it consumes more than 15 cubic feet per hour. The use of small automobile tanks should

be discouraged, only the very lightest work can be done and the cost of the gas is considerably more than it is when using the regular welding cylinder.

*When would you advise the use of "tanked" Acetylene?*

When only occasional welding or cutting is done or where portability is desired.

*When would you advise the use of a generator?*

When stationary welding or cutting is done, using about 200 cubic feet of acetylene or more per week.

*What is the saving over tanked Acetylene per 100 cubic feet?*

The difference between 80c for generator gas and $2.50 for tanked gas, or $1.70.

*Has the tanked gas any disadvantages?*

Yes.

*Name them.*

(1) Inconvenience and delay in shipping tanks.

(2) No assurance that you receive full amount of gas in tank.

(3) Some gas always remains in the tank.

(4) The solvent (acetone) mixes with the acetylene and produces a bad weld.

(5) Certain make of tank not your property.

(6) Likelihood of leakage from tank greater than from generator on account of higher pressure.

(7) Lack of sufficient gas to finish a job.

(8) Hazard.

*Explain each of the above.*

### INCONVENIENCE AND DELAY IN SHIPPING TANKS.

The inconvenience and delay incident to shipping tanked acetylene is a serious problem. Delays in shipment will necessarily occur, and they usually occur when the welding plant is most needed. But, with the very best possible time, it is usually two or three days before a full tank is received. One of the important values of a welding plant is *readiness to serve.* Anyone familiar with custom welding realizes that 75% of the repair work must be gotten out in a hurry. It is rush work, and your value to the customer increases when you are in a position to at all times take care of the work promptly.

### NO ASSURANCE THAT YOU RECEIVE FULL AMOUNT OF GAS IN TANK.

With tanked acetylene you must depend upon the correctness of the companies recharging the cylinders. A gauge on the tank will only indicate the pressure of the gas—not the *quantity* of gas. No one but

the recharging people can tell how much gas is in a cylinder as the amount of gas depends not only upon the size of tank and the pressure, but also *upon the quantity and quality of the solvent—acetone—in the tank.* It takes a smart man that can look through a steel tank and tell how much acetone is on the inside, and there is no way for the customer to measure it. No one questions the honesty of any of the firms engaged in the filling of acetylene tanks, but their employees are human; they are likely to make mistakes; and as a matter of fact they do sometimes make mistakes.

SOME GAS ALWAYS REMAINS IN THE TANK.

With tanked gas you never get all the gas out of the tank. A quite considerable amount of gas remains and is shipped back to the recharging station to be resold to you in your next tank.

THE SOLVENT (ACETONE) MIXES WITH THE ACETYLENE AND PRODUCES A BAD WELD.

When tanked acetylene is used, the gas from a full tank will produce an excellent weld, but as the pressure and the amount of gas in the tank is lowered, the acetone or solvent comes off also, adulterating the acetylene, contaminating it with a hydro-

carbon of less heat units and consequently lowering the temperature of the flame. This acetone also contains impurities which affect the strength of the weld. That the acetone is carried off and burned with the acetylene is evidenced by the fact that one of the refilling companies at one time made a charge of 2c per ounce for whatever loss of acetone was shown when the tank was returned.

### A CERTAIN MAKE OF TANK NOT YOUR PROPERTY.

Acetylene tanks are simply loaned by one of the different concerns compressing acetylene under a "Service Agreement," for which they charge, and you are compelled by the agreement to get your recharges from them. You do not own the tank. It is not even leased to you. You simply pay a certain amount for the privilege of buying their gas and you cannot go into the open market and buy your acetylene.

### LIKELIHOOD OF LEAKAGE FROM TANK GREATER THAN FROM GENERATOR ON ACCOUNT OF HIGH PRESSURE.

The pressure of the gas in the high pressure generator cannot exceed 15 pounds. The pressure of the gas in an acetylene tank is at least 225 pounds, and maybe more. It must be obvious that the likeli-

hood of leakage is greater under the higher pressure.

### LACK OF SUFFICIENT GAS TO FINISH A JOB.

It often occurs that a welding job comes in which will take a fair amount of gas. Perhaps a part of the gas in your tank has been used on other work and not enough remains to do this particular job. What are you going to do? You can use what gas is in the tank to partially weld the casting, then send your empty tank in and write or wire for another full one. This means that the casting cools down and you have lost your heat, which cost money; besides, distortion often occurs on account of this cooling when only partially welded. You could send the partially full tank back at once and order a full tank, but this means loss of gas in the tank returned.

### HAZARD.

Any power-producing agency has inherent hazards, and acetylene is no exception. A generator of good design and workmanship possesses no greater hazards than a compressed or dissolved acetylene tank. Some tanks have exploded; so have some generators; so that any claims to the contrary, it is a stand-off between the two on the question of hazard.

*What are the disadvantages of a generator?*

First, there is a slight variance in pressure of the gas between locking and releasing the motor. This necessitates occasional adjustment of the flame by means of the torch cocks. This is largely overcome by means of a special regulator.

Second, recharging the generator and removal of sludge requires about twenty minutes. The indolent may offer this as an objection.

Third, cost of generator is much more than cost of a tank.

Fourth, some precautions must be taken to prevent freezing in winter.

Fifth, generators should not be moved when filled with carbide, and used for portable work.

Sixth, generator house should be provided, which necessitates an expense.

*What fuel gas is best adapted for welding?*

Acetylene.

*Why?*

The temperature of an acetylene flame when burned with oxygen is in excess of 6300° F. This is a temperature exceeding by over 2000° F. its nearest rival, hydrogen. It is the flame temperature that

counts in welding and not the B. T. U.'s of a gas.

*What are some of the gases that have at various times tried to compete with Acetylene?*

Hydrogen, Blau gas, Wolf gas, thermolene, oxy-carbo, etc.

*What are the objections to the above?*

First, it is impossible to do heavy welding unless these gases are enriched with acetylene.

Second, usually, the cost of doing such work as is practical, is more than it would cost using actylene when all factors, such as labor, are considered.

*Why does Acetylene, when burned with oxygen, give us the hottest fuel flame known?*

Broadly speaking, the gas which has the greatest amount of carbon and the least amount of hydrogen will give us the hottest flame. Acetylene contains by weight 93% carbon, almost approaching gaseous carbon. There is another property which acetylene possesses, which assists in increasing the flame temperature and it is the fact that it is an endothermic compound.

*What is meant by an Endothermic Compound?*

It is a compound whose formation from elementary substances is attended with absorption of heat. The electric furnace has made the manufacture of carbide practicable. Authorities differ as to whether calcium carbide, when formed, absorbs or liberates heat, but they are agreed that when carbide and water are brought together slacked lime and acetylene are formed and that the former liberates heat, while the acetylene absorbs heat. When the acetylene is burned, this absorbed or stored-up heat is liberated, and helps to increase the flame temperature.

*What is it that limits the temperature of the Oxy-Acetylene flame?*

The dissociation point of carbon monoxide—(C.O.).

*What is meant by the dissociation point of an inflammable gas?*

It is the temperature at which the gas refuses to unite with oxygen.

*At what pressure does Acetylene liquefy?*

At 26 Atmospheres (282 lbs.)—At 32 Degrees F.
At 40 Atmospheres (588 lbs.)—At 70 Degrees F.

*What is Copper Acetylide?*

It is a compound which is formed when acetylene is exposed for a considerable time to copper.

*What properties, if any, does this compound possess?*

It is explosive.

*What lesson do we learn from this?*

That under no condition should copper be used when it will come in contact with acetylene.

*What is the density or specific gravity of Acetylene?*

Assuming air to be unity or 1, it is .91 for acetylene. It is therefore slightly lighter than air.

*Does Acetylene, when burned, give off any Ultra Violet Rays?*

It does not, so that no harm can come to the eyes from this score. However, it must be remembered that any bright light will in time tire and weaken the eyes so that it is strongly recommended that smoked glasses be worn.

*What is the weight of a cubic foot of Acetylene?*

.069 of a pound.

*How many cubic feet of Acetylene does it take to weigh a pound?*

14.5 cubic feet.

*What is the ignition temperature of a mixture of Acetylene and air?*

About 805°F.

*What concerns manufacture Carbide?*

American Carbolite Company.
Canadian Carbide Company.
Union Carbide Company.

*What companies furnish compressed Acetylene?*

Commercial Acetylene Welding Company.
Prest-O-Lite Company.
Searchlight Company.

*What is the policy of each company with reference to furnishing the gas?*

The Commercial Acetylene Company seldom sell any of their tanks. They usually loan them to responsible people without charge. They furnish tanks having a capacity of 125 cubic feet, 250 cubic feet and 500 cubic feet.

The Prest-O-Lite Company manufactures two sizes of tanks, one of which contains practically 100 cubic feet of gas and the other 300 cubic feet. They charge under a service agreement $20.00 for the small size, and $40.00 for the large size tank.

The Searchlight people charge $30.00 for the small tank, and $60.00 for the large tank.

Each of these companies will refill only their own tanks.

*Which compressed Acetylene companies offer the best proposition to the user?*

The Commercial Company is the only one of the three who furnish the tanks free.

The reader can judge for himself as to whether he would prefer to pay for the tanks or simply have them loaned. It must be remembered that service is a very important consideration, and in some cases it is advisable to purchase the tanks in order to get prompt delivery.

*Are there any hazards in connection with Acetylene?*

There are some who believe in minimizing the hazards in connection with acetylene. The writer does not belong to that school. Any sensible man realizes that any power-producing agency, whether it be steam, electricity, gasoline or acetylene holds within itself possibilities for good or evil. It would seem that one way of avoiding accidents with acetylene is to apprise and thoroughly familiarize one's self with its properties. When properly handled, acetylene will unite in a molten mass, a 6x6 inch iron beam, and the same power which accomplishes this wonder of yesterday will play havoc if one becomes careless and refuses to follow a very few simple and common sense rules. Millions upon millions

of feet of acetylene, both tanked and generated, are used yearly with but a trifling number of accidents as compared with the installations.

A few acetylene tanks and generators have exploded. Where the explosion occurred inside the generator, it was seldom of a serious character. Where considerable damage results it is usually caused by the gas leaking out in considerable quantities in the room from the tank or the generator and mixing with the air. Never under any circumstances try to find a leak with a lighted match. Elsewhere we will advise more fully as to the care that should be observed when working with acetylene.

## CHAPTER II.

### Oxygen.

*What is Oxygen?*

Oxygen is an element. It is the most abundant and most widely distributed of all the elements, constituting by weight more than one-fifth the air, and eighth-ninths of all the water on the globe. It enters largely into the solid constituents of the earth's crust, and is found in the tissues and fluids of all forms of animal and vegetable life.

Oxygen is a colorless, tasteless gas and is essential to the support of all animal life.

*What is the density or specific gravity of Oxygen?*

Assuming air to be unity or 1, it is 1.105 for oxygen. It is, therefore, slightly heavier than air.

*How many cubic feet of Oxygen does it take to make a pound?*

11.209 cubic feet.

*What does a cubic foot of Oxygen weigh?*

.08921 of a pound or 100 cubic feet weighs 8.92 pounds.

*What are some of the various methods of making or procuring Oxygen?*

(1) Red oxide of mercury.

(2) Sodium peroxide.
(3) Chlorate process, with either potassium chlorate or sodium chlorate.
(4) Brin's process or the use of barium oxide.
(5) Lavoisite process.
(6) Electrolysis of water.
(7) Liquid Air.

*Describe each?*

Oxygen can be obtained by heating red oxide of mercury. This is purely a laboratory experiment, not being commercially practical. Its only interest lies in the fact that this method was the first one employed to produce oxygen.

### SODIUM PEROXIDE PROCESS.

Sodium peroxide is a yellow solid which when brought in contact with water liberates oxygen. This process is extremely simple. Each pound of sodium peroxide will produce two cubic feet of oxygen of high purity. The market price of the chemical is high so that the cost of oxygen by this method is excessive, ranging from about 12 to 20 cents per cubic foot. This method is employed to some extent in procuring oxygen for medicinal purposes, used mainly in conjunction with nitrous oxide (laughing gas) as an anaesthetic.

### CHLORATE PROCESS.

Potassium chlorate when heated alone to a temperature of about 350° F. gives off oxygen. It has been found that if manganese dioxide is mixed with the potassium chlorate in the proportion of about 100 pounds of potassium chlorate to 14 pounds of the manganese that it does not require so much heat to liberate the oxygen—only about 200° F., so that in practice this is usually done. If sodium chlorate is used, the amount of manganese is increased somewhat. Potassium chlorate will give off about five cubic feet of oxygen per pound and the sodium chlorate will produce about 12% more oxygen per pound. Sodium chlorate is not so stable a compound as potassium chlorate, and the latter chemical was in much greater favor than the former.

At the prevailing prices of these chemicals before the European War, the gas could be made for about 2 cents per cubic foot, and of a purity ranging from 85% to 98%, depending entirely upon the method and care exercised in purifying.

There were two methods of making oxygen by this process. One consisted in generating the gas under its own pressure and was designated by the trade as a "Self-Compressing" type. The gas made by this

method was of low purity and was attended by hazards of so serious a character that the better class of manufacturers tried to discourage its use. The other method consisted of heating the chemicals in a sealed retort, allowing the gas to pass through several scrubbers and purifiers, collecting in a gas holder and then compressing into tanks. The present price of chemicals makes this method impractical.

### BRIN'S PROCESS or BARIUM OXIDE PROCESS.

In this method of making oxygen, barium oxide is used and the gas is produced by the alternate formation of barium dioxide and its decomposition into barium oxide. The installation of a plant requires considerable space and special heating requirements are necessary so as to produce a working temperature of 800° F. The process consists in heating barium oxide and directing upon it a blast of air, when it takes up oxygen from the air and forms barium dioxide ($BaO_2$). The temperature is then raised and the barium dioxide decomposes into barium oxide and oxygen. The process is theoretically simple, but in practice presents certain serious difficulties. At one time several of these plants were operating in this country, but they

were not a commercial success and were abandoned.

### LAVOISITE PROCESS.

This is a trade name, lavoisite being a chlorine product. The process consists in bringing together the chemical and water that has been heated to about 180° F., when oxygen is evolved. One pound of lavoisite and one-half pound of water will produce one cubic foot of oxygen of excellent purity. The cost is about the same as the chlorate process.

### ELECTROLYSIS OF WATER PROCESS.

Oxygen and hydrogen are liberated when a suitable electric current is passed through water whose conductivity has been increased by the addition of either an acid or an alkali. From the positive pole will pass oxygen and from the negative pole will pass hydrogen. There will be generated 2 cubic feet of hydrogen for each 1 cubic foot of oxygen. The vessel in which the electrolytic action takes place is called a cell. This cell is divided or separated into two chambers by means of a partition—usually of pure asbestos cloth. The object of this partition is to keep the two gases—hydrogen and oxygen—from mixing, so that it is of the highest importance that these asbestos diaphragms or partitions be of the very best of material in order that

the danger from rupture shall be minimized. Should the hydrogen and the oxygen be allowed to mix, it would be attended by very grave danger, as even so low a mixture as 5% hydrogen and the remainder of oxygen or vice versa will explode.

Oxygen made by this process is usually of an excellent quality; gas 98% pure should be obtained direct from the cells and if purified will be in excess of 99% pure.

Various types of cells are offered the public. The claims of the manufacturers as to the efficiency range anywhere from 3 to 3.8 cubic feet of oxygen and twice that amount of hydrogen per kilowatt hour. Probably 3½ cubic feet of oxygen would be a conservative figure. Assuming that an electric current rate of one cent per K. W. H. was obtained, 100 cubic feet of oxygen would cost 28 cents. To this must be added interest on investment, depreciation, labor, overhead and cost of compressing into tanks. This is on the assumption that the hydrogen is not marketable. However, in recent years there has been created a quite considerable demand on the part of soap and cottonseed lard manufacturers for hydrogen, for what is known as "oil-hardening." Where the hydrogen can be utilized, this effects a very material saving

in the cost of the oxygen and under these conditions the electrolytic process will be a strong competitor with any process. A number of industrial concerns throughout the country have installed small electrolytic plants, primarily to obtain hydrogen. This gives them as a by-product a very limited amount of oxygen and some are attempting to market it. We would strongly advise against the use of this gas and unhesitatingly recommend that the customer purchase oxygen only from those concerns who are engaged primarily in the oxygen business, for the reason that the concern whose principal business is the manufacture and sale of oxygen is not only much more apt to appreciate the necessity for pure gas, but as his reputation is at stake will undoubtedly more frequently test his gas for impurities than the concern who is in the business merely as a side-issue.

### LIQUID AIR PROCESS.

Obtaining oxygen by the liquid air method is a refrigeration process. By compressing the air and then allowing it to expand through a small opening a temperature sufficiently low to liquefy the air is obtained. This temperature is 374° below zero F. at atmospheric pressure—a temperature so cold that it is almost impossible to realize it. The nitro-

gen is allowed to evaporate, leaving liquid oxygen behind. The liquid oxygen is in turn allowed to gasify and is led to suitable gas holders, from which it is compressed into steel drums or tanks. The perfection of this process is due very largely to the efforts of Linde, Claude and Hildebrandt.

It is possible to obtain oxygen of a high purity by this process. About 20% is added to the manufacturing cost by increasing the purity from 92% to 97%, and further increasing the purity to 99% entails an additional 10% to the manufacturing cost. From this it will be readily seen that there is always the temptation during exceedingly busy times to decrease the purity of the gas. The impurity in liquid air oxygen is nitrogen, an inert gas. The cost of oxygen by this process depends upon the size of the installation and whether the plant is operated continuously. Claude, in his work on Liquid Air, Oxygen and Nitrogen, states that oxygen can be made "for 2 centimes the cubic meter." A centime is equivalent to one-fifth of a cent and a cubic meter is equal to 35.3 cubic feet, so that this amount of gas would cost two-fifths of a cent, or 100 cubic feet of gas would cost one and one-fifth cents. If these figures are correct, he did not take into consideration, depreciation, labor, overhead, etc.

*What is the present market price of Oxygen?*

From 1¼ cents per cubic foot, to very large users, to 2 cents per cubic foot to small users.

*In what kind of containers is Oxygen furnished?*

In steel drums in which the gas is compressed to about 1800 pounds.

*When a gas is compressed to so high a pressure, is there not danger of leakage at the tank valve?*

Yes. The purchaser should insist on valves that will open and close easily and which will not leak around or through the packing gland regardless as to the position of the valve stem.

*What is the policy of the various Oxygen Companies with reference to furnishing the steel drums?*

To responsible parties they will furnish the tanks free for a period of 30 days, but they retain the right to make a rental charge of a small amount for the tank if it is not returned within the 30 days.

*What capacity tanks are usually furnished?*

100 cubic feet, 150 cubic feet, 200 cubic feet and 250 cubic feet.

*Does the temperature of the air affect the pressure in the tank?* Yes.

*How?*

As the temperature increases the pressure of the gas in the tank increases on account of it expanding and as the temperature decreases, the pressure drops.

*Give table showing the different pressures at various temperatures?*

**Table of pressures per degree for tanks carrying 1800-lbs. at 68 degrees F. Pressure in pounds per degree at any temperature from zero "F." to 100 degrees above zero "F." inclusive, with the volume remaining constant at all times.**

| Temp. Deg. C. | Press. Lb. Per. Deg. | Temp. Deg. F. | Press. Lb. Per. Deg. | Temp. Deg. F. | Press. Lb. Per. Deg. | Temp. Deg. F. | Press. Lb. Per. Deg. |
|---|---|---|---|---|---|---|---|
| 0 | 1568 | 26 | 1657 | 51 | 1743 | 76 | 1828 |
| 1 | 1572 | 27 | 1660 | 52 | 1746 | 77 | 1831 |
| 2 | 1575 | 28 | 1664 | 53 | 1749 | 78 | 1835 |
| 3 | 1579 | 29 | 1667 | 54 | 1753 | 79 | 1838 |
| 4 | 1582 | 30 | 1671 | 55 | 1756 | 80 | 1842 |
| 5 | 1585 | 31 | 1674 | 56 | 1760 | 81 | 1845 |
| 6 | 1589 | 32 | 1678 | 57 | 1763 | 82 | 1848 |
| 7 | 1592 | 33 | 1681 | 58 | 1766 | 83 | 1852 |
| 8 | 1596 | 34 | 1684 | 59 | 1770 | 84 | 1855 |
| 9 | 1599 | 35 | 1688 | 60 | 1773 | 85 | 1859 |
| 10 | 1603 | 36 | 1691 | 61 | 1777 | 86 | 1862 |
| 11 | 1606 | 37 | 1695 | 62 | 1780 | 87 | 1865 |
| 12 | 1609 | 38 | 1698 | 63 | 1784 | 88 | 1869 |
| 13 | 1613 | 39 | 1701 | 64 | 1787 | 89 | 1872 |
| 14 | 1616 | 40 | 1705 | 65 | 1790 | 90 | 1876 |
| 15 | 1620 | 41 | 1708 | 66 | 1794 | 91 | 1879 |
| 16 | 1623 | 42 | 1712 | 67 | 1797 | 92 | 1883 |
| 17 | 1626 | 43 | 1715 | 68 | 1800 | 93 | 1886 |
| 18 | 1630 | 44 | 1719 | 69 | 1803 | 94 | 1889 |
| 19 | 1633 | 45 | 1722 | 70 | 1807 | 95 | 1893 |
| 20 | 1637 | 46 | 1725 | 71 | 1811 | 96 | 1895 |
| 21 | 1640 | 47 | 1729 | 72 | 1814 | 97 | 1900 |
| 22 | 1643 | 48 | 1732 | 73 | 1818 | 98 | 1903 |
| 23 | 1647 | 49 | 1736 | 74 | 1821 | 99 | 1906 |
| 24 | 1650 | 50 | 1739 | 75 | 1824 | 100 | 1910 |
| 25 | 1654 | | | | | | |

*Of what value is this table?*

If the temperature to which the tank has

been exposed is known, by referring to the column adjoining, there is shown the pressure that the tank should be under if it is what is known as a "full" tank. As an example, suppose the temperature was 32° F., and the tank had been exposed to this temperature sufficiently long for the gas to be cooled to the same point, then the pressure on the gauge would indicate 1678 pounds. On the other hand, assume that it was summer and the temperature 97° F. Then the pressure should be 1900 pounds. In both cases there was the same amount of gas in each tank, but the pressures differed, due solely to the gas in the latter case expanding and in the former contracting as the temperature varied.

*We see from the table above that temperature affects the pressure of gas. Is there any fixed rule for determining this?*

It has been found that for every change in temperature of one degree Fahrenheit there is a corresponding change in volume which amounts to 1/491 of the original volume of the gas. If a gas occupying one cubic foot of space under a temperature of say, 70° F. would be raised to a temperature of 71° F., the volume would be in-

creased 1/491 of one cubic foot. For each change in temperature of one degree Fahrenheit there is a corresponding change in pressure of approximately 3.42 pounds.

*What does this suggest?*

That some certain degree of temperature should arbitrarily be chosen as a standard from which to measure oxygen.

*Has this been done?*

Yes. Most oxygen companies have taken 70° F., some 68° F.

*How do you determine the contents of a cylinder under pressure?*

It is first necessary to know the contents of the cylinder at atmospheric pressure. This is determined by multiplying the area of the head by the length of the cylinder. The area of the head is obtained by multiplying the square of the diameter by .7854. Thus a cylinder having a diameter of 2 feet and a length of 3 feet will have a cubical contents of—.7854x(2x2)x3 or 9.4248 cubic feet. After the cubic contents have been found it is only necessary to multiply this by the pressure in atmospheres to find the cubic contents under any pressure.

*What is an atmosphere?*

It is the pressure of the air at sea level and has been definitely determined to be

14.7 pounds, but for rough calculation 15 pounds is generally used.

*If a cylinder has a cubic contents of one cubic foot at atmospheric pressure (zero gauge pressure), what would be the cubic contents at* 1800*-pound pressure?*

The 1800-pound pressure is reduced to atmospheres by dividing by 15 pounds or one atmosphere. The 1800 pounds is found to be equivalent to 120 atmospheres. The cubic contents of the cylinder—1 cubic foot—is then multiplied by 120, the number of atmospheres of pressure and a product of 120 cubic feet is obtained. In other words, there is enough gas in this tank which is under 1800 pounds pressure to fill a tank of 120 cubic feet capacity under only ordinary atmospheric pressure.

*In practice how is the amount of Oxygen in a tank determined?*

Most manufacturers of apparatus have a gauge marked on the dial to read both in pounds pressure and in cubic feet.

It may be of interest to some to know the amount of gas in the different size of oxygen cylinders under varying pressures. We accordingly give a table herewith for tanks holding 100, 150 and 200 cubic feet of gas under 1750 pounds pressure.

| Press in Lbs. per Sq. In. | 100 cu. ft. Tank Cu. Ft. | 150 cu. ft. Tank Cu. Ft. | 200 cu. ft. Tank Cu. Ft. |
|---|---|---|---|
| 15 | .855 | 1.282 | 1.710 |
| 30 | 1.710 | 2.565 | 3.420 |
| 45 | 2.565 | 3.84 | 5.120 |
| 60 | 3.42 | 5.13 | 6.84 |
| 75 | 4.275 | 6.4 | 8.55 |
| 90 | 5.13 | 7.69 | 10.26 |
| 105 | 5.985 | 8.97 | 11.97 |
| 120 | 6.84 | 10.26 | 13.68 |
| 135 | 7.695 | 11.53 | 15.39 |
| 150 | 8.55 | 12.82 | 17.1 |
| 200 | 11.4 | 17.1 | 22.8 |
| 250 | 14.25 | 21.37 | 28.5 |
| 300 | 17.10 | 25.65 | 34.2 |
| 350 | 19.95 | 29.92 | 39.9 |
| 400 | 22.8 | 34.2 | 45.6 |
| 450 | 25.65 | 38.47 | 51.3 |
| 500 | 28.5 | 42.7 | 57. |
| 550 | 31.65 | 47.47 | 63.3 |
| 600 | 34.50 | 51.7 | 69. |
| 650 | 37.35 | 56. | 74.7 |
| 700 | 40.2 | 60.3 | 80.4 |
| 750 | 43.05 | 64.57 | 86.1 |
| 800 | 45.09 | 68.8 | 91.8 |
| 850 | 48.75 | 73.12 | 97.5 |
| 900 | 51.6 | 77.4 | 103.2 |
| 950 | 54.45 | 81.67 | 108.9 |
| 1000 | 57.5 | 86.2 | 115. |
| 1050 | 60.35 | 90.52 | 120.7 |
| 1100 | 63.2 | 94.8 | 126.4 |
| 1150 | 66.05 | 99. | 132.1 |
| 1200 | 68.9 | 103.3 | 137.8 |
| 1250 | 71.75 | 107.6 | 143.5 |
| 1300 | 74.60 | 111.9 | 149.2 |
| 1350 | 77.45 | 116.17 | 154.9 |
| 1400 | 80.20 | 120.3 | 160.4 |
| 1450 | 83.05 | 124.5 | 166.1 |
| 1500 | 85.9 | 128.8 | 171.8 |
| 1550 | 88.75 | 133.12 | 177.5 |
| 1600 | 91.5 | 137.2 | 183. |
| 1650 | 94.35 | 141.5 | 188.7 |
| 1700 | 97.2 | 145.8 | 194.4 |
| 1750 | 100.05 | 150. | 200.1 |

*Does the purity of Oxygen have any influence on welding or cutting?*

Any impurity in the oxygen will lower its efficiency. This is not so noticeable in welding if the impurity is not in excess of 2% or 3%, but in cutting it is claimed that even a 1% impurity is apparent not only as to the time and the quantity of oxygen necessary to do the work, but also the appearance of the cut.

Some years ago, Mr. J. M. Morehead in a paper read before the International Acetylene Association, presented the results of test on the cutting power of oxygen of varying purity. His table follows:

METAL CUT MILD STEEL PLATE ¾" THICK.

| Exp. No. | Pur. of Oxy. | Lgth. of cut in inches | Time in seconds | Total Oxy. used; cu. ft. | Time per ft. of cut in sec. | Oxy. used per ft. of cut | % inc. in Oxy. consumption | % inc. in time occupied | Appearance of Cut |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 99.3 | 67¾ | 272 | 7.5 | 48 | 1.3 | Taken as Unit | | Very good |
| 2 | 98. | 67½ | 285 | 9.1 | 51 | 1.6 | 23% | 6% | Good cut |
| 3 | 97.6 | 67¾ | 295 | 9.8 | 52 | 1.7 | 31% | 8% | Fair cut |
| 4 | 96.8 | 68¼ | 363 | 11.8 | 64 | 2. | 54% | 33% | Fair cut |
| 5 | 96.4 | 67½ | 360 | 11.3 | 64 | 2.1 | 61% | 33% | Ragged and cindery |
| 6 | 95. | 67½ | 377 | 11.6 | 67 | 2. | 61% | 39% | Ragged, dirty and cindery |
| 7 | 92. | 67½ | 551 | 16. | 98 | 2.7 | 108% | 104% | Very dirty and rough |
| 8 | 87.3 | 67½ | 660 | 16.2 | 117 | 2.9 | 123% | 114% | Blew back badly, very rough |
| 9 | 83.3 | 67¾ | 855 | 18.9 | 153 | 3.4 | 154% | 214% | Very rough and ragged, not properly cut |

Subsequent to the publication of this table, the writer experimented along the

same lines. While we were never able to show so marked a difference in the cutting power between pure oxygen and that of lesser purity as indicated by Mr. Morehead, still the difference was such as to justify us in recommending that users of oxygen insist upon being furnished oxygen of a high degree of purity.

# CHAPTER III.

## Welding and Cutting Torch.

### THE OXY-ACETYLENE WELDING TORCH.

*What are the requisites for a good welding torch?*

The oxy-acetylene welding torch should be simple of design, light, yet sufficiently strong in its construction and provide for the bringing together of oxygen and acetylene and mixing these gases in the correct proportions.

Fig. 2.
An Oxy-Acetylene Welding Torch.

*Of what does a welding torch consist?*

It consists of a handle through which pass two conduits or tubes, one of which is for the acetylene and the other for the oxygen. These tubes are each provided with cocks or valves and they in turn are connected to the hose which carry the gases from their source of supply. The other

ends of the two tubes are firmly connected with what is known as the torch head. It is either here or in the tip itself that the mixture is accomplished. Tips of various sizes are usually furnished.

*In the manufacture of a torch what have been the chief difficulties to overcome?*

First, the tendency to "flash-back," and second, a waste of oxygen.

*What produces a "flash-back"?*

Primarily it is produced by allowing the velocity or speed of the mixed gases (acetylene and oxygen) to drop below the speed of propagation of the flame. This occurs when the pressure in the acetylene generator or tank becomes low. This may occur by reason of the partial obstruction of pipes or openings in the torch or tips.

*What is meant by "the velocity of propagation of the flame"?*

The speed with which a mixture of acetylene and oxygen will travel when ignited.

*How fast does a mixture of Acetylene and Oxygen travel when lighted?*

About 330 feet per second.

*What do we learn from this?*

That the two gases when mixed should be under a pressure sufficient to insure a speed of over 330 feet per second when

the mixture escapes from the nozzle of the tip.

*How does this prevent a "flash-back"?*

If the gases passing out of the tip are traveling at a speed of, say, 350 feet per second, then if the flame can only travel 330 feet per second, it follows that the flame cannot pass into the torch. The unignited gases traveling faster will always push the flame away from the tip.

*What is meant by a "waste of Oxygen" in a torch?*

Two and one-half volumes of oxygen are required to completely consume one volume of acetylene. Theoretically one and one-half volumes of oxygen can be taken from the air and one volume from the tanked gas. So much for theory. It is almost an axiom that one never obtains in practice what they should in theory. The oxy-acetylene torch is no exception. Instead of one cubic foot of tanked oxygen being consumed for each one cubic foot of acetylene, in practice the best torches use from 10 to 15% more oxygen than acetylene and any increase in this amount means among other things a waste of oxygen.

*How are welding torches classified?*

According to the pressure of the acetylene.

*How many and what are these classes in this country?*

There are two:

1st—Those using low pressure acetylene and

2nd—Those using what is called high pressure acetylene.

*What is meant by Low and High Pressure Acetylene?*

The terms are simply comparative. "Low pressure" torches are those designed primarily to use acetylene from a generator or gas-holder in which the pressure is about three inches of water column or practically two ounces.

"High pressure" torches are those designed to use acetylene at a pressure of from one pound in the smallest tips to as high as ten pounds in the largest tips. The acetylene is taken either from a tank in which the gas is compressed or from a special pressure acetylene generator. It will be seen that the highest pressure used —ten pounds—is really not a high pressure except as compared with the "low pressure" torch using about two ounces. There has been some objection to the use of the term "high pressure" for fear that the public might construe "high" pressure to possibly mean a dangerous pressure, and some have preferred to use the

term "medium" pressure. The terms high pressure and medium pressure as used in this country are synonymous. There is no more danger working under ten pounds pressure than there is under two ounces.

*How is a low pressure torch constructed?*

The acetylene under a few ounces of pressure flows into a compartment through which the oxygen is passing at a high velocity. The high speed of the oxygen draws or sucks in the acetylene. This is what is known as the injector principle.

*How is the high pressure torch constructed?*

Both the acetylene and oxygen are under a few pounds pressure. These gases flow through openings accurately determined into a mixing chamber from which they are conveyed to the nozzle.

*Which type of torch is considered the best?*

The high pressure.

*Why?*

Because numerous tests have proven that in practice, the high pressure torch of good design using the acetylene under a few pounds pressure consumes practically equal quantities of acetylene and oxygen, whereas the low pressure torch requires an excess of oxygen ranging from 10% to 30% more than high pressure

torches, depending upon the size of the tip. In a series of experiments conducted by the Engineering Experiment Station of the University of Illinois the proportion of acetylene at normal regulation averaged 42% in the low pressure torch. This is a ratio of 1.38 volumes of oxygen to one of acetylene. A good high pressure torch will not use nearly so much oxygen.

*Are there any authorities whose tests prove the above assertion?*

Yes.

*Name a few of them and state briefly what they have to say?*

"For blow pipes of high pressure all the experiments agree in showing that the respective volumes of gas used are practically equal, and this is obtained in practice if the operators are competent."

"The blow pipes for low pressure acetylene are those with which the most difficulty has been obtained even in approaching the theoretical equal volumes."

GRANJON & ROSEMBERG.

"In the high pressure type the adjustment of the flame is far easier with both gases under pressure; once the adjustment is made right it remains so; a more intimate mixing of the gases is obtained than in the low pressure type, and this secures

higher efficiency. This is of considerable importance, as it is found that with high pressure blow pipes considerably less acetylene and oxygen is required to do a fixed quantity of work than is necessary with the low pressure blow pipe."

L. A. GROTH.

"In the high pressure type torch, both gases being under pressure maintain quite accurately their relative proportions when once properly adjusted. In the injector or low pressure torch, each change of temperature of the blow pipe or of the tip forming the outlet causes some variation in the size of the opening and consequently variations in the relative proportions of the issuing gases."

WHITTEMORE.

"The low pressure torch is defective in that it very often does not carry enough acetylene through it to neutralize the effect of the oxygen, consequently the weld is oxidized."

RICHARD HART.

"All burners or torches with oxygen under pressure and acetylene without pressure, *i. e.*, injector type, become after a short time of working practically useless."

"The radiating heat affects the oxygen which is under pressure, with great veloc-

ity in a narrow space in a different way than its action upon the acetylene contained in a larger space and without pressure."

"The result is a decomposition of the flame and a burning of the metal."

"This can only be prevented by a skillful welder."

DR. A. HILPERT, Berlin.

In the low pressure torch, the acetylene is drawn into the tip by the suction of the oxygen operating by a device known as the Giffard Injector. In the injector type of torch the amount of acetylene drawn in, varies as the square of the oxygen.

*What chemical changes take place when Oxygen and Acetylene are burned?*

It may be well to state that all combustion, with the exception of some unimportant laboratory experiments, is the result of combining carbon with oxygen, hydrogen with oxygen, or combinations of hydrogen and carbon, called hydro-carbons, with oxygen. As stated before, acetylene is a hydro-carbon. That is, it contains both hydrogen and carbon. The layman when watching the phenomenon of combustion is apt to consider its action as destroying something. Such is not the case. It is

simply a chemical change and invariably combustion finally produces carbonic acid gas or carbon dioxide ($CO_2$) and water or water vapor ($H_2O$). In order to properly explain the change or reaction that takes place it becomes necessary to use symbols, but in this case they are simple and we feel sure they will be easily understood.

It may be advisable to state here some of the symbols which we will use, together with what they stand for.

H is the symbol for hydrogen.

C is the symbol for carbon.

O is the symbol for oxygen.

CO is the symbol for carbon monoxide.

$CO_2$ is the symbol for carbon dioxide or carbonic acid gas.

$H_2O$ is the symbol for water or water vapor.

$C_2H_2$ is the symbol for acetylene.

Acetylene ($C_2H_2$), as previously stated, is composed of equal parts of hydrogen and carbon and it unites with an equal volume of oxygen ($O_2$) to form the first reaction. This reaction is indicated by the following equation:

$$(a) \quad C_2H_2+O_2=2\ CO+H_2$$

In other words, 1 molecule, which is the

technical expression for a unit volume of acetylene, unites with 1 molecule of oxygen. A unit volume of oxygen is expressed as $O_2$ and is made up of two parts or atoms of oxygen.

The primary stages of combustion as indicated in equation (a) result as indicated in production of 2 unit volumes of carbon monoxide (2 CO) and 1 unit volume of hydrogen ($H_2$) which, like oxygen, is made up of two parts or atoms. Now these products of the primary stage of combustion are formed in the small, bluish-white cone of the flame. This is shown in Fig. 3.

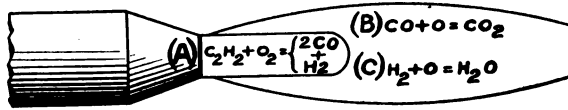


Fig. 3.

This cone is the zone of greatest heat in the flame. The secondary or final stage of combustion takes place in the outer flame which not only surrounds the small white cone, but extends for quite a considerable distance beyond it. In this outer flame, the carbon monoxide (2 CO) and the hydrogen ($H_2$) which were shown to have been produced in the small white cone are transformed by the addition of more oxygen

to carbon dioxide or carbonic acid gas ($CO_2$) and water vapor ($H_2O$). This change would appear to be two-phase and may be better understood by the following equations:

(b) $H_2+O=H_2O$
(c) $CO+O=CO_2$

The changes that take place as shown by equations (b) and (c) do not and cannot occur in the small white cone of the flame, for the reason that a temperature of 6300° F. is produced at this point, and hydrogen and oxygen will not unite to form water vapor above 3600° F., and carbon monoxide and oxygen will not unite to form carbon dioxide at a temperature higher than 2272° F. In other words, the hydrogen and the carbon monoxide must get outside and away from the small white cone where it is cooler before combustion can take place.

*Does the small white cone or the outer flame or both take oxygen from the tank or the air?*

This is a very important point and one which the conscientious manufacturer of welding apparatus has seriously studied. Upon its solution depends whether the torch will be economical or expensive in the consumption of oxygen. Enough oxy-

gen should be supplied from the tank for the combustion that takes place in the small white cone and it should stop there. The outer flame will take its oxygen from the air if it is permitted to do so. As the tanked gas cost money and the air is free and as the outer flame is not for welding, economy would dictate that as much air as possible be used. It is a notable fact that in the low pressure torch, the tendency is for the oxygen, by reason of its high pressure, to pass through the small white cone and supply the outer flame with a part of this element. This will always be an objection to the low pressure type of torch.

*What other objections does the low pressure torch possess?*

In a series of experiments carried out in France by the Union of Autogenous Soldering some six different torches using low pressure acetylene were tested to determine, first, just what the ratio of oxygen to acetylene was shortly after ignition, and second, whether the ratio was constant after the torch had been in operation for some time and had become thoroughly heated. The results of these tests are as follows:

| Torch | Consumption of acetylene per hr. | Consumption of oxygen per hr. shortly after ignition | Consumption of oxygen per hour after torch became hot |
|---|---|---|---|
| A | 20 Cu. Ft. | 28. Cu. Ft. | 36. Cu. Ft. |
| B | 6 Cu. Ft. | 8.1 Cu. Ft. | 10. Cu. Ft. |
| C | 12 Cu. Ft. | 19.2 Cu. Ft. | 22.8 Cu. Ft. |
| D | 16 Cu. Ft. | 26.4 Cu. Ft. | 30.4 Cu. Ft. |
| E | 20 Cu. Ft. | 29. Cu. Ft. | 31. Cu. Ft. |
| F | 26 Cu. Ft. | 40.3 Cu. Ft. | 45.5 Cu. Ft. |

It will be seen from this table that there was a considerable increase in the consumption of oxygen upon the torches becoming heated. This was found to occur only in torches using low pressure acetylene. The effect of expansion on the two gases operating at such a marked difference in pressures is not the same.

*The claim has been made here that the high pressure torch is more efficient than the low pressure torch. Will all high pressure torches uphold this contention?*

Not at all. There are inefficient high pressure torches due to poor design, or poor workmanship or both. In a series of tests with a number of torches in which the acetylene consumption was fixed at 10 cubic feet per hour it was found that the best result showed 12% more oxygen consumed than acetylene; the worst 90% more

oxygen than acetylene, while the average was 33⅓%.

The result of these tests should convince those who are using autogenous welding, or who are contemplating using it, that a few pieces of brass do not constitute an efficient welding torch.

*One would gather from the above that while the gas pressures used in the various high pressure torches were practically the same, the manner in which the gases mix must be different.*

That is correct. Some high pressure torches mix in the tip, some in the head and others in or near the handle of the torch.

*Which is the best type of high pressure torch?*

In the first place, practically all torches now have interchangeable tips. These tips vary in size, producing a small, medium or large flame, as may be desired. Inasmuch as metal varies in thickness, this permits of producing a welding flame of suitable size for the work at hand. The writer is strong in the belief that the torch which provides a separate and distinct mixture for each individual tip, will come the nearest to theoretical perfection. To illustrate, Fig. 4 shows a cut of such a tip.

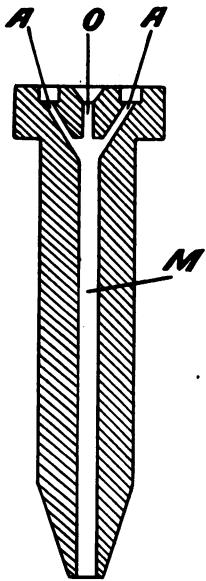

Fig. 4.

"O" is the oxygen inlet. "A" "A" is an annular chamber in which there are a number of holes drilled to meet the oxygen inlet. These openings form the acetylene inlets to a mixing chamber and nozzle "M." Between inlet "O" and inlets "A" "A" there is a flat seat or seal which prevents the gases from mixing until they reach their proper destination. As the mixing chamber and nozzle "M" varies for each tip, so the oxygen inlet "O" and the acetylene inlets "A" "A" vary accordingly, being proportioned to supply the correct amount of acetylene and oxygen under the proper pressures.

It must be clear that the amount or volume of gas passing through an opening depends upon the pressure and the size of the opening. Now the pressure is controlled by the regulators, and with a tip of this design it is a simple matter to drill

the proper openings, once they have been correctly determined.

Those torches which mix in the head or near the handle provide no means of accurately changing the volumes. They simply provide for one mixture and of course this must be for their largest tip. When lighter work is desired a smaller tip which chokes down the flow of the gas is used. There can be no real accuracy of mixture with such a design.

## THE CUTTING TORCH.

*What metals can be cut with the torch?*

Wrought iron and steel are the only metals which can be cut with oxygen.

*Why?*

Cutting with oxygen is simply a burning of the metal—a rapid oxidation. The slag formed is called oxide or iron oxide. This oxide has a much lower melting point than that of the metal and as the burning or cutting progresses the oxide is detached, leaving clean iron for the oxygen to attack.

Copper, brass, aluminum and cast-iron cannot be cut. These metals not only do not oxidize in the same degree as wrought iron or steel, but in addition the oxide which does form has a melting point equal or higher than that of the metal and this prevents it from being detached.

*Of what does the operation of cutting consist?*

It consists first in heating the wrought iron or steel to redness and then directing upon the heated section a jet of oxygen escaping under a pressure which varies ac-

Fig. 5.
An Oxy-Acetylene Cutting Torch.

cording to the thickness of the metal to be cut.

*In order to cut economically and to secure a clean, smooth cut, what is necessary?*

That the torch be moved at a regular, even speed and that the speed shall approach as near as possible the maximum rate at which the steel is attacked by the oxygen; that pure oxygen shall be used and that the oxygen jet shall be held as close to the steel as possible. This last is very important. As a matter of fact, the author, after considerable experimenting, perfected a cutting torch in which the oxygen jet rests directly on the metal that is being cut. That this is correct in practice is shown by the cut, which in the ma-

jority of cases is as smooth as a shear cut.

We believe that an explanation as to the theory is convincing in that respect. Any gas when escaping from an orifice does not continue in a straight line, but commences to diverge almost at the instant it passes out of the opening. This is illustrated by Fig. 6.

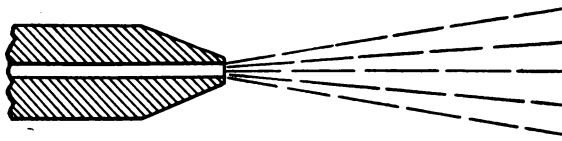

Fig. 6.

Now it must be apparent that if the oxygen opening is say ⅛ of an inch in diameter that the diameter of the oxygen jet must be about ½ inch more or less when measured a distance of one inch from the nozzle, and this diameter decreases as we approach nearer the nozzle. The center or core of this oxygen jet is probably pure oxygen, but undoubtedly the outer fringe is contaminated with air which contains 80% nitrogen and it is this outer fringe that is responsible for the appearance of the edge of the cut—whether clean and sharp or rough and cindery. Elsewhere we have shown the effect of impure oxygen in cutting and if the results of these tests

can be relied upon it bears out the above claims.

Another advantage in resting the oxygen jet directly on the metal is that the cut is narrower, therefore less metal has been burned and the operation is more economical.

*Who were probably the first to use oxygen for cutting?*

Dr. Menne, a German, and Jottrand, a Belgian.

*Theoretically, how much oxygen is required to cut a given amount of steel?*

As previously stated, the steel when cut is transformed into iron oxide or more properly magnetic oxide of iron, the chemical symbol of which is $Fe_3 O_4$. The atomic weight of iron is 55.9 and that of oxygen 16, so that the weights of the iron (Fe) and the oxygen (O) in the iron oxide are in the proportion of 168 to 64 or 21 to 8. The oxygen needed will then be 8/21 times the weight of the steel involved, or 38% of the weight of the steel removed. Assuming that the kerf or cut has a thickness or width of ⅛-inch, the weight of steel corresponding to each square inch of the face of the cut is .0352 pound, and 38% of this is .01338 pound, the weight of oxygen necessary to make the cut. A pound of oxygen at 32° F. occupies 11.2 cubic feet

of space, and .01338 pound is found to be .15 cubic foot. Therefore, theoretically it requires .15 cubic foot of oxygen to cut a square inch of steel if the kerf is ⅛-inch wide.

*In practice what amount of oxygen has been found necessary?*

Just about double the theoretical amount. It must be remembered that the above has considered only the amount of oxygen required in the oxygen jet. To this must be added the oxygen and the acetylene consumed in the heating jets.

*Is there any detrimental change in material when cut with oxygen?*

No. On high carbon steels there is a slight softening of the metal for a distance of about ⅜-inch from the cut, due to the annealing effect of the heat. Numerous tests have been made and all bear out the above assertion. The results of one such test may prove interesting. A steel plate ¾-inch thick and 14¾-inch long was used.

| TEST NO. 1. ORIGINAL STOCK BEFORE CUT. | TEST NO. 2. AFTER CUT. |
|---|---|
| Tensile.....47,620 lbs. | 50,110 lbs. |
| Elastic Limit..31,640 lbs. | 29,930 lbs. |
| Elongation.....33% | 33% |
| Reduction of area...35% | 42% |

*Can a fuel gas other than acetylene be used in the pre-heating jet?*

Yes. Ordinary coal gas, Pintsch gas, hydrogen or any good hydro-carbon gas can be used.

Hydrogen has been used quite extensively for cutting, and for extremely heavy work would seem to be better adapted than acetylene. The hydrogen flame is a long one, whereas the acetylene flame is short, and this is probably the reason why on very thick metal hydrogen would seem to be better adapted.

The cost depends largely upon the price at which the two gases can be purchased, and when any comparison is made the market price of each, together with the consumption, should be stated.

## CHAPTER IV.

### Apparatus and Installation.

### REGULATORS AND REDUCERS.

The above names used to designate a part of the welding and cutting apparatus would appear to be used synonymously in this country. However, the function of a regulator would seem to be wider in its scope than that of a reducer. A good regulator is a very essential part of any welding or cutting equipment.

*What is the duty or function of a regulator?*

Primarily to reduce the pressure of the oxygen as it flows from the cylinder, and the pressure of the acetylene from its tank, or the generator as the case may be. Its secondary duty is to maintain the desired reduced pressure without fluctuating. Almost any type of regulator will fulfill the first requirement, but only a high grade one combines both features.

*How are regulators constructed?*

They all utilize the diaphragm principle. The diaphragm is either of metal or rubber composition and attached to one side of the diaphragm is a seat which covers and closes the opening in a nipple communicating with the gas cylinder. There is a spring which rests against the other

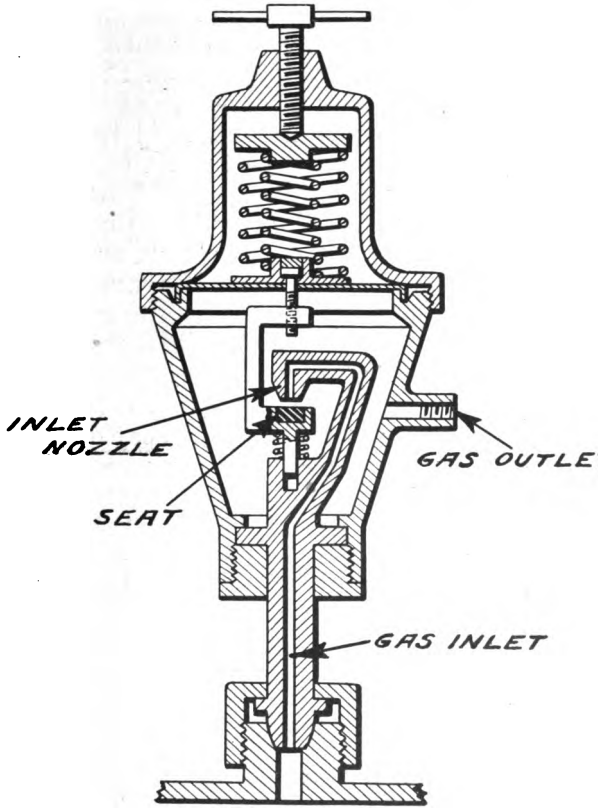


Fig. 7.
An Oxygen Regulator.

side of the diaphragm. When there is no tension on this spring, the parts are so

adjusted that the diaphragm holds the seat over the nipple, closing the gas inlet tight, so that no gas can escape from the container. When some tension is put on the spring, the diaphragm is pushed inward, releasing the pressure of the seat on the nipple and allowing the gas to flow into the body of the regulator. The pressure of the gas climbs until it exceeds the tension of the spring when the diaphragm is pushed outward, again closing the gas inlet. The gas that is in the body of the regulator is used up by the torch until the pressure drops to a point where the spring tension is the stronger, and the seat opens, allowing gas to again enter the regulator. This continues regularly and might very aptly be compared to breathing. If the seat is perfect, and the flexibility of the diaphragm correctly proportioned to the stiffness of the spring, a very sensitive regulation can be obtained.

*Should an oxygen regulator be provided with a cock or valve at its outlet?*

No, for the reason that if a cock is furnished at the outlet, there is always the temptation for the operator, when the torch is not in use, to shut off the gas at this point rather than at the tank valve. If the regulator seat should leak, trouble might result, whereas if there was no cock a

burst hose would be the only bad result.

*What are some of the points to be observed in order to keep a regulator in good condition?*

As stated above, the diaphragm is continually breathing or moving and of course the seat is subjected to considerable wear by the reason of its frequent closing and opening of the inlet nipple. If the seat is not perfect, it is of no value and so care must be taken that the movement of the diaphragm closing the seat is not sudden, as the seat will pound on the nipple and quite likely be destroyed. This is caused by the operator opening the tank valve while there is tension on the regulator spring, so if you expect your regulator to give good service, see that the spring tension is released before turning on the gas.

We have just seen how the regulator seat could be injured by the diaphragm being suddenly forced outward by the incoming gas. The diaphragm itself may be put out of commission and possibly injury done the seat by reducing from a higher to a lower pressure with the outlet closed.

To illustrate, suppose that the torch is welding on heavy work which requires an oxygen pressure of 18 or 20 pounds and it is necessary to do some light welding. This requires a small tip with an oxygen

pressure of 2 or 3 pounds. If the thumb screw is backed out, releasing the tension on the spring there will be little or no tension against the diaphragm on the spring side and it will be forced outward, and in time so buckle the diaphragm that it will be useless. Therefore, when reducing from the higher to a lower pressure the outlet should always be open.

*What is meant by a leaking regulator?*

A regulator leaks when the seat does not completely seal the opening in the inlet nipple and allows the gas from the tank to enter the body of the regulator. A leaking regulator is detected by the hand on the low pressure gauge, which is usually the small gauge, creeping up. When the hand indicator on this gauge shows the pressure creeping 15 or 20 pounds more than the pressure shown when the torch is operating, then there is a serious leak and it is dangerous to continue using a regulator under this condition. When this occurs the regulator should be returned to the manufacturer for repairs. While some undoubtedly would be able to repair their own regulators, in the vast majority of cases it would be much more satisfactory to return them to the manufacturer who would be in a position to put them in first-class shape.

It is important that no grease or oil be allowed in the interior of the regulator. If this should be done it might cause an explosion.

## GAUGES.

The better class of apparatus manufacturers equip oxygen regulators with two gauges, one of which is a 3000-lb. gauge and the other ranging from 50 pounds to 150 pounds. The 3000-lb. gauge usually reads not only in pounds pressure, but also in cubic feet, so that by glancing at this gauge the operator can instantly note both the pressure in the tank and the cubic contents. The other gauge, which is usually of smaller diameter, indicates the pressure under which the torch is operating. The 3000-lb. gauge should be provided with what is known as a safety back so that in the event that the spring should prove defective and burst, injury to the operator will be avoided.

## GOGGLES.

Tinted or smoked goggles should always be worn by those welding. The tint or degree of color depends entirely upon individual taste. For welders doing general repair work a light-smoked and also a dark-smoked goggle should be provided, the lighter colored goggle being used on alum-

inum, brass or small castings, while the darker goggles should be worn on heavy cast-iron and steel work.

Some welders unquestionably wear glasses of too dark a color, the strain on the eye trying to see the work being as injurious as if they wore none at all. The best color is the one which does not tire or strain the eye.

### ACETYLENE GENERATOR.

One of the most important units that comprise an oxy-acetylene welding plant is the acetylene generator. As previously stated, these are of two types, namely low pressure and high pressure. Nearly everyone is familiar with the low pressure generator by reason of the fact that it is simply a lighting generator. The high pressure generator produces the acetylene under a few pounds pressure.

*What are the important considerations in an acetylene generator?*

They are:

1st—Safety.
2nd—Cool generation.
3rd—Automatic feed.
4th—Minimum variance in pressure.
5th—Good mechanical construction.

*What devices should be placed on a generator to insure safety?*

The most important consideration from

a standpoint of safety is that the feeding mechanism on the generator should be arranged so that it will lock when a given amount of gas has been generated and this means when a given amount of carbide has been fed into the water. If the locking device did not operate, it must be apparent that an excess amount of gas would be generated.

In the low pressure generator the gas might break the water seal and so escape into the room.

In the high pressure generator an excessive pressure might occur.

Safety blow-offs are provided on all first-class generators and these, if operating, would prevent the gas from escaping into the room, but in any event there would be a loss of gas which would be pure waste.

A flash-back cylinder is necessary on either type of machine. While the chance of the flame flashing back in the generator is rather remote, yet there is the possibility of such a thing happening and safety devices of this kind should be attached to all generators.

### COOL-GENERATION.

Under the head of Acetylene cool-generation was briefly described. By this is

meant: supplying a sufficient amount of water to dissipate or keep down the heat of generation. It is imperative that one gallon of water should be supplied for each one pound of carbide in the generator.

### AUTOMATIC FEED.

*What is meant by Automatic Feed?*

By this is meant that the generator will automatically without attention feed carbide and thereby generate gas for the torch as it is being used, and will cease generating when the torch is not in use. Some machines do not do this and it seriously interferes with the welder, as it is necessary for him every few minutes to leave his work and feed by hand some carbide.

### MINIMUM VARIANCE IN PRESSURE.

In the low pressure generator there is practically no variance in pressure. With the high pressure generator there is and must be a slight variance in pressure. It is this slight difference in pressure which is taken advantage of to start and stop the feeding mechanism. This variance in pressure should not exceed a pound or two and this is taken care of by means of a special regulator for high pressure generators.

## GOOD MECHANICAL CONSTRUCTION.

It is admitted by all that any machine should have good mechanical construction and the only difference arising is as to what constitutes good mechanical construction. It is the opinion of the writer that welding generators should be built very much more substantial than the ordinary acetylene lighting generator, for the reason that very much more work is demanded of the welding generator than is of the lighting machine.

Some machines have the body of generator riveted and soldered. We are strongly of the belief that this is a mistake. The generator, of course, must be gas-tight and as the rivets do not produce a gas-tight joint, soldering is resorted to. The sheets are usually galvanized iron. Sheet metal workers have long since learned that where solder is applied to galvanized stock if the parts are subject to any movement or strain the galvanizing will peel and, of course, as the solder is attached to the galvanizing it means a loose and leaky joint. The pressure in the acetylene generator varies and this causes a breathing of the body or tank portion and in time the solder breaks loose and the gas leaks into the room. Too often in attempting to solder up these loose joints an open light has

been used with fatal results. The best generators have all of the seams and connections welded. It would seem to reflect upon the oxy-acetylene process to do otherwise.

The motor which operates the feeding machine should be strong and substantial. If there is any possible chance of gears in time stripping or breaking, devices should be arranged to automatically lock the motor.

### PORTABLE GENERATORS.

There are some firms who advocate the placing of an acetylene generator upon a truck and using it for portable work. The writer cannot condemn in too strong terms such practice. There is no objection in moving the generator when there is no carbide in it to where the work is to be done and then charging the generator, but to move a generator containing carbide and water through buildings where there are large insurable values is a great mistake and is apt to result in loss of property and possibly life.

### DIRECTIONS FOR CONNECTING UP TANK OR PORTABLE WELDING OUTFIT.

We shall take up first the installation of a welding unit in which both the acetylene and the oxygen are used from tanks

or cylinders. These are known by the trade as "tank" outfits. Before attempting to light the torch, the novice should thoroughly learn how the different parts should be assembled, and he should know the function of each separate part of the equipment.

(1) With the portable or tank outfit it is necessary to have two tanks. One of these contains oxygen, and it is so stamped or labeled. The other contains acetylene, and this tank is plainly marked acetylene. They are both gases, but have entirely different properties. Learn to call them by their correct names of oxygen and acetylene.

(2) All oxygen tanks have a cap for protecting the tank valve in shipment. Remove this cap by unscrewing and attach the oxygen regulator, being sure that the coupling nut is drawn up tight to prevent leakage. It is impossible to attach the wrong regulator as only the oxygen regulator connection will fit the oxygen tank valve. Then attach the oxygen hose to the regulator outlet.

(3) If a Prest-O-Lite Acetylene tank is used, an adapter must first be screwed into the tank valve. This adapter has a left-hand screw connecting to the tank. If Commercial Acetylene or Searchlight tanks

are used the adapter is not necessary. When outfit is ordered, you should specify which make of acetylene tank you contemplate using so that the manufacturer may furnish the right connection. If a Prest-O-Lite tank is used, when the regulator is connected it will be upright. If Commercial or Searchlight tank is used the regulator will form a right angle with the tank. Be sure that the connection is tight and well made so that there will be no leaks. Then attach the acetylene hose to the regulator outlet.

(4) Attach the oxygen hose to the cock at the torch handle which is stamped with the letter "O" or with the word oxygen. With most torches this is the upper cock. Then attach the acetylene hose to the cock at the torch handle which is stamped with the letter "A" or with the word acetylene. With most torches this is the lower cock.

(5) The correct welding tip should be selected and screwed tightly into the torch head. Practically all manufacturers furnish a table showing the size of tip that should be used for different thicknesses of metal. These tables are practically correct, but some latitude must be allowed, as the mass of metal and the kind of metal will necessitate some variation.

(6) Now see that the regulator screws on both the acetylene and oxygen regulators are entirely released—that is, backed out or turned to the left until they are free of tension.

(7) SLOWLY open the oxygen tank valve when the pressure and contents will register on the dial of the 3000-lb. gauge.

(8) Open the acetylene tank valve and the pressure of the gas in this tank will register on the dial of the 500-pound gauge.

(9) Turn the acetylene regulator screw to the right slowly until the number of pounds pressure registered on the small gauge is the same as shown in the manufacturer's table under the head of acetylene for that size of tip. This small gauge indicates the acetylene pressure being delivered through the hose to the torch.

(10) Turn the oxygen regulator screw to the right slowly until the number of pounds pressure registered on the small gauge is the same as shown in the manufacturer's table under the head of oxygen for that size of tip. This small gauge indicates the oxygen pressure being delivered through the hose to the torch.

(11) Open the acetylene torch cock and light the acetylene and then slowly open the oxygen cock and continue to open until the neutral flame is obtained. Occasionally

open or close one of the torch cocks to see that proper flame regulation is being maintained.

(12) While operating should the flame pop out, what is commonly called a "back-flash" has occurred. This is caused by one of three things:

First —The tip becoming overheated.

Second—A piece of molten metal flying up and momentarily closing the orifice of the tip.

Third —By an insufficient amount of pressure of either acetylene or oxygen.

Should this occur, you should quickly close first the oxygen torch valve and then the acetylene torch valve. Then relight the torch.

Sometimes in operating a welding torch the smaller tips work correctly, but trouble is experienced in getting the larger tips to stay lighted. If upon investigation none of the three troubles mentioned above are responsible, then it is quite likely that dirt has gotten in the torch tubes and partly closed some of the openings. This dirt can come from the hose or other causes. By partly closing the openings they will still be large enough to supply enough gas for the smaller tips, but will not be large enough for the larger tips.

It will therefore, be necessary to attach a hose to the tip end of the torch and by using either compressed air or oxygen from the tank blow the dirt out through the handle.

## DIRECTIONS FOR INSTALLING GENERATOR WELDING OUTFIT.

### GENERATOR INSTALLATION.

We now come to installation of a welding plant which uses acetylene from a generator instead of from a compressed tank. The first question that suggests itself is regarding the foundation.

### GENERATOR FOUNDATION.

This may be of brick, stone, concrete, iron or of wood. If of wood then it should be of extra heavy timbers arranged so that the air can circulate around them and arranged so as to form a substantial and firm base. It should be seen that the generator is level and that no unequal strain is placed on it or any of the connections.

We would strongly recommend that where possible the generator be placed outside of insured buildings in properly constructed generator houses. This is greatly to be desired, particularly if the insurable values are high, for the reason that if the generator is located outside in a separate detached building most, if not all,

of the states make no charge to the insurance rates, whereas if the generator is located inside of any of the main buildings there is an increased premium rate. The generator should be placed so that there will be ample room both for the machine and the attendant to perform his required duties. Windows or skylights should be provided so there will be no need for artificial light. In climates where there is danger from freezing, proper protection should be provided to guard against it. Steam or hot water heat only should be used.

### ESCAPE OR VENT PIPES.

All generators of standard make are provided with an escape or vent pipe. This should be of ample size, in no case to be less than ¾-inch internal diameter. This pipe should be installed without traps and so that any condensation will drain back to the generator. It must be carried to a suitable point outside the building and terminate in a hood located at least 12 feet from the ground. The hood must be constructed in such a manner that it cannot be obstructed by rain, snow, ice, insects or birds.

### CAPACITY.

Generators should be of sufficient capacity to furnish gas under working con-

ditions from one charge of carbide to all torches installed, for at least one working period of one-half day or 4½ hours. For the better class of machines—carbide feed—the rating has been fixed at *one cubic foot of gas per hour, per pound of carbide.* As an example a 50-pound machine, that is; one having a capacity of 50 pounds of carbide per charge, would have a rated capacity of 50 cubic feet of acetylene per hour.

## PIPING.

Connections from the generator to service pipes should preferably be made with right and left couplings or long thread nipples with lock nuts. Where unions are used these should be of a type which obviates the necessity for using gaskets. Where possible, the piping should be arranged so that any moisture will drain back to the generator. If low points necessarily occur in any piping, it should be drained through tees into drip cups permanently closed with screw caps or plugs. In no event use pet-cocks.

In large installations where the service pipe extends a considerable distance, the main service pipe should be broken at a point as close to the generator as possible. The connection here should be made out of strong and substantial rubber hose. The

object of this rubber hose is to secure electrical insulation. Some accidents have occurred by reason of electricity used in the plants grounding on the acetylene service pipe and causing a spark while the generator was being charged. Insulation as recommended above will prevent this.

The schedule of pipe sizes for piping from the generator to torches should conform to that commonly used for ordinary gas, but in no case must feeders be smaller than ⅜-inch.

Generators should not be directly connected to sewers, but should discharge into suitable open receptacles which may be provided with an overflow pipe connected to the sewer. Piping should be carefully tested when system is completed. It must not show a loss in excess of 1 pound within 12 hours when subjected to a pressure of 8 pounds.

### CARE AND MAINTENANCE.

Generators should be cleaned and recharged as nearly as possible at regular stated intervals. This work, as well as any repairs, should be done during daylight hours only when artificial light is not needed. When artificial light is absolutely necessary, this must be provided by incandescent electric lights enclosed in gas tight globes. In charging generator clean

all of the residue out thoroughly, and then fill with the required amount of water. Never charge with carbide unless generator is filled with water. Always keep flash-back chamber filled with water.

### CONNECTING REGULATORS.

When the generator and the service piping leading therefrom has been installed, attach the acetylene generator regulators to the piping at the various locations previously determined as welding stations. Connect the acetylene hose to the regulator. Individual oxygen tanks can be used at the various welding stations or a number of oxygen tanks can be connected to a manifold provided with a regulator and the gas piped at a reduced pressure wherever required. Connecting the torch is the same as for the tank plant.

### A FEW DON'TS.

Never recharge generator without first cleaning out the generating chamber and completely refilling with water.

Never test the generator or piping for leaks with a flame, and never apply flame to any open pipe or at any point other than the torch. In testing for leaks use soap and water.

Never use a lighted match, lamp, candle, lantern or any open light near the generator.

# CHAPTER V.

## Preparing for Welding.

### TOOLS NECESSARY FOR REPAIR WELDING.

Probably 90% of those who purchase welding apparatus already have all necessary tools for the welding shop, but for the benefit of the remaining 10% we would say that one should have a vise, clamps, files, stillson and monkey wrenches, tongs, chisels, hammer, forge, stationary emery and if possible a portable one also, chain-block, V-blocks, square and straight edge, portable kerosene torch, a number of small pieces of iron or steel ranging in thickness from that of a saw-blade on up, to be used as shims, hack-saw, about 200 fire brick, roll of asbestos paper, and a welding table.

The welding table is the only accessory that requires a description. If one is in a town where there is a scrap-iron dealer, a cheap and serviceable table can usually be found in his scrap pile and obtained for the price of ordinary junk. If possible, secure an old casting that has been machined on one side and is at least two or three inches thick so that it will not be easily warped by the heat. An old planer

bed makes an excellent table if you should be fortunate enough to find one. If it is impossible to procure such a casting, then it will be necessary to make a table about 30 inches high of either angle iron or bar stock and cover it with brick.

### CLEANING THE METAL.

The edges to be welded and the immediate vicinity of the weld should be thoroughly cleaned. Not only will the welding be facilitated by doing so, but it also prevents the dirt, oxide, etc., from being incorporated in the molten metal and assisting if not actually forming blow-holes.

If the work is well cleaned, less flux will be required and that which is used will do its work better.

### BEVELING.

Where the metal to be welded is of a thickness of 3/16 of an inch or more, the edges should be beveled so that when the two pieces are placed together they form an angle of at least 90 degrees.

In steel of $\frac{3}{8}$ of an inch in thickness or more this bevel should be of an even greater angle.

Beveling can be accomplished by either grinding, chipping or sawing and it is necessary for several reasons. By removing the metal, this allows the flame to get

down to the bottom and work its way up and it permits of adding a greater quantity of metal of better quality. Some welders do not bevel, but depend upon the torch to flow the metal out or they dislodge it when molten by means of a rod.

In the great majority of cases this is bad practice. Occasionally where it would be difficult to "line up" the casting after it was ground, beveling may be dispensed with. Those welders who make a practice of welding without beveling will be very apt to be troubled with "come-backs" and an examination of their work will determine that they have not welded all the way through, or that they have burned the metal.

When the part to be welded is ¾ of an inch thick or more, it is best to bevel and weld on both sides if it is possible to do so.

## PRE-HEATING METHODS AND DEVICES.

### CHARCOAL.

Probably the first method of pre-heating was the use of charcoal. This fuel is still used to a considerable extent. It has the advantages of a slow heat, an even one and a fairly high temperature. The slow heat, while an advantage on some castings is a disadvantage on others. There is one serious objection and that is the disagree-

able fumes which accompany its combustion.

### ARTIFICIAL OR NATURAL GAS.

In the cities and in certain sections of the country, it is possible to procure one of the above gases. Where gas can be obtained, this makes an ideal fuel for pre-heating when used in connection with properly designed torches. The inlet service main into the building should be sufficiently large to furnish an adequate flow of gas. This pipe should not be less than 2 inches in diameter. For cylinder work, or where the pre-heating is primarily to take care of expansion and contraction a torch using the gas with ordinary atmosphere air is best adapted. This torch is constructed on the Bunsen burner principle and is sold by almost all manufacturers of welding apparatus. A torch of this kind gives a soft flame of not too concentrated a heat.

If the pre-heating is entirely or mainly for the purpose of economy in the use of acetylene and oxygen, then the gas should be burned with a torch using compressed air. When used with compressed air a more concentrated flame of higher temperature is secured—just the thing for work of this character.

Torches of either of the two types are made in different sizes and the consumption of gas will range from 100 to 200 cubic feet per hour. At $1.00 per 1000 cubic feet, they will cost from 10c to 20c per hour.

Fig. 8.

Kerosene Pre-Heating Torch

### KEROSENE AND GASOLINE TORCHES.

For outside or portable work one of the above torches is very desirable. They are not well adapted for expansion and contraction pre-heating, their field being largely that of heating up heavy castings in order to save in the use of acetylene and oxygen. Compressed air, usually obtained by a hand pump, is used with either fuel. The kerosene torch will be found to be more economical to operate and will give a higher temperature. These torches are also manufactured and sold by the leading welding manufacturers.

### FURNACES FOR PRE-HEATING.

We have seen the different fuels that can be used for pre-heating castings preparatory to welding. Now the casting is not heated out in the open for the reason that there would be too great a loss of heat and the casting would be subjected to the direct influence of drafts. It has been found necessary when heating the casting to enclose it in either a temporary or a permanent furnace. There are a few who advocate the use of a permanent furnace, but unless this work is all of the same size the extra outlay for such a furnace is a useless expense; besides, they are usually extravagant with fuel. The most practical

and economical furnace is a temporary one built from loose fire brick, whether charcoal, gas or kerosene fuel is used.

The bricks are simply laid one upon the other, leaving a space of from 6 to 12 inches around the casting, depending upon its size. If charcoal is used, the bricks are spaced near the bottom, leaving cracks through which the air which feeds the fire can pass. The top is covered with sheet iron or asbestos. If gas is used spacing of the brick is not necessary, the only openings required being those through which the gas torches pass. If the heating is to take care of expansion and contraction, the gas torches should not be turned directly on the casting, but should be made to impinge directly on the brick. This will cause the flame to whip around the casting and thereby secure a more even heat. If the primary object of the heating is a saving of acetylene and oxygen then the pre-heating torch can play directly on the casting.

### EXPANSION AND CONTRACTION.

All metals are affected by heat. The action of heat produces an increase in volume; that is, a casting when heated has greater length, breadth and thickness. This is called expansion and as a general proposition this expansion increases progressively as the temperature increases. As

the casting cools its volume begins to get less, until at normal temperature it usually assumes its original size. This is called contraction. It is well to remember that you cannot stop a casting from expanding when it is heated. This force is irresistible; no power can prevent it. Do not attempt to prevent a casting from expanding by means of clamps. If you should be so foolish as to try, and the clamps were strong enough, distortion of the casting would inevitably result. As most castings are of irregular shape, and the metal usually varies in thickness, it is necessary to take some precautions in heating so that the heavy parts will expand in the same ratio as the thin parts. If this is not done either breaking or distortion is very apt to occur. This precaution is *uniform heating* and in order to secure a uniform heat *slow heating* is necessary. For pre-heating of cylinders and like castings in order to take care of expansion, remember to heat *slowly* and *uniformly* and of course to take care of contraction *cool* slowly and uniformly. That is the "meat in the cocoanut," heating slowly and uniformly and cooling slowly and uniformly. When the foundryman made the casting it was poured from molten metal possessing the same temperature throughout and flowed into a mold where

it was entirely protected from the air by the sand, which permitted an even and uniform cooling. Welding with the oxy-acetylene flame is simply re-casting and the beginner would do well to study and follow foundry practice in a number of instances.

Unless the beginner studies and thoroughly understands the principles of expansion and contraction and applies it to the work at hand he will not be a success, regardless as to how well he may manipulate the torch. In the majority of cases it is just as important to maintain alignment as it is to make a good weld. If the welder ignores expansion and contraction, it is inevitable that one of three things will happen:

1st —The casting on cooling will break in or near the weld.

2nd—Distortion of the work destroying alignment.

3rd—The weld may not break and distortion may not occur, but there will be a *strain* in the casting, causing the welded portion, or near it, to snap and break when the load is placed on the machine.

A good way to illustrate the effects of expansion and contraction and one apparently popular with those writing on the subject is represented by Figures 9, 10, 11

and 12. Figure 9 represents a bar which is broken at "A." In this case the weld can be made without giving any attention to expansion and contraction in view of the fact that the ends "B" are free. Of course, while

Fig. 9.

being welded the heat will expand it, but there is nothing holding it and it can increase its length as well as its breadth and thickness, and when it cools it comes back into its original position. Now in Figure 10, B A B represents the same bar, except

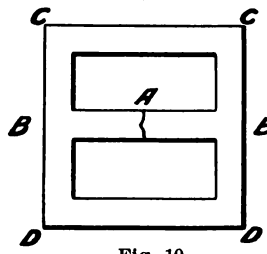

Fig. 10.

that now it is the middle member of a frame. The length, breadth and thickness is the same, the break is the same as is also the location. The only difference is that the ends "B" are now a part of the

sides C B D. Let us assume that we make the weld exactly as we did when the bar was not a part of the frame.

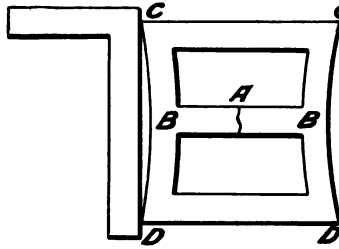


Fig. 11.

No difficulty would be experienced in making the weld, but upon cooling it would probably break. However, if it did not break and we sight down the edge C B D

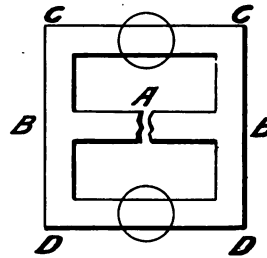


Fig. 12.

it will appear to be "sway-backed" and if we place a straight edge along this surface (Fig. 11) we can easily see that it does not touch at "B" and is somewhat concave.

Now when the weld at "A" cooled, B A B became shorter by reason of contraction and being stronger than C B D it pulled these two sides in. The casting is not only warped and out of alignment, but a considerable strain is also set up. It must be plain that considerable power was required to bend C B D and this tension is what is known as the strain. The proper way to make this weld is shown in Fig. 12.

The ends "C" and "D" are heated and expand and the break at "A" opens. We can now proceed to make the weld without fear of bad results. The ends "C" "D" and the weld "A" all cool down together, leaving the casting in alignment and without a strain.

This is perhaps the simplest illustration that could be given of expansion and contraction. Each case must be studied. Some experimenting will have to be done and some failures will be recorded. A good rule to follow is—"When in doubt pre-heat the entire casting."

## MELTING POINTS OF METALS.

While it is not necessary to know the various melting points of metals and alloys in order to do good welding, such information will likely prove interesting and instructive.

| Metal | Melting Point | Metal | Melting Point |
|---|---|---|---|
| Platinum | 3200° F. | Silver | 1750° F. |
| Soft Steel | 2700° F. | Brass | 1700° F. |
| Hard Steel | 2550° F. | Bronze | 1650° F. |
| Nickel | 2500° F. | Aluminum | 1200° F. |
| Cast Iron | 2100° F. | Zinc | 850° F. |
| Red Copper | 1900° F. | Tin | 650° F. |

Authorities differ considerably as to the above temperatures. We have taken the figures of several and arrived at a mean temperature which should be sufficiently correct for comparative purposes.

REGULATION OR ADJUSTMENT OF THE FLAME.

Elsewhere we have shown how to assemble the welding unit and how to light

Fig. 13.

Acetylene Only Burning.

the torch. The next and one of the most important things is the question of adjustment so that a neutral flame will be obtained and maintained. The acetylene should be lighted and as the acetylene torch cock is slowly opened, it will be seen that the flame jumps a very slight distance away from the end of the tip when using a small size, and as the size of the tip increases this space increases likewise, until

in a very large tip the flame will be separated from the end of the tip by possibly 3/16 of an inch. We now turn on the oxygen by slowly opening the torch cock. The first thing we notice is that the entire flame assumes a more brilliant and whiter color. A slight increase in the oxygen and we see that the end of the flame commences to take on a yellowish cast and the white section is shortening. A further increase in the amount of oxygen tends to increase the

Fig. 14.

Excess of Acetylene.

amount of yellow and diminish the amount of white. We have now what is known as a carbonizing flame. By that is meant that there is not enough oxygen. The white portion has what is commonly called a "ragged" edge. If welding is done with this kind of a flame the metal is almost sure to be hard and difficult to machine. We slowly further increase the amount of oxygen and as we do so, we can see the white portion drawing within itself or shortening up. When the last straggling edge disappears and the white cone is round and well defined, it is then we have the much

talked of *neutral* flame. The length of this small white cone should be about 2½ times its diameter. This is the proper flame for welding. If the oxygen is further increased the white cone shortens, becomes more pointed and the hissing sound of the gas escaping is materially increased.

Fig. 15.

Correct or Neutral Flame.

This is what is called an oxidizing flame. By that is meant too much oxygen is being furnished and the work is sure to be burned.

Fig. 16.

Excess of Oxygen.

The beginner should practice lighting his torch for an hour or more. A hundred times he should light his torch, adjust the flame, turn off the gas and relight again, until he is absolutely satisfied that he knows what a neutral flame is and how to procure it.

When the neutral flame is once secured

it does not follow that it will continue neutral indefinitely. On the contrary it will quite likely vary somewhat. This will instantly be detected by the experienced welder by its effect on the metal. However, this treatise is intended primarily for the beginner—the neophyte—and not for the experienced, and so the thing to do is every now and then test the flame by slightly closing the oxygen torch valve until the flame is carbonizing, and then again slowly opening it up until a neutral flame is obtained. The trade speaks of the small, blue-white flame as the "cone" and of the outer flame as the "envelope." It is well that one should know these terms and speak of them properly.

## EXECUTION OF A WELD.

We have already told how to install a welding outfit, how to light and regulate the torch and how to set up or prepare the work. The next thing is how to execute a weld. Whether the welder sits or stands upright is of no importance.

The torch is held firmly, but not rigidly, and a steady hand is of prime importance. Welding should progress forward in a direction away from the operator. The angle at which the torch should be held depends upon the thickness of the metal, but for the

average class of work a slightly inclined forward position is the one that will be found best. For light sheet metal work where no filler rod is used the angle of inclination becomes less, whereas for heavy work the torch will be held almost perpendicular to the work.

In welding the torch should not be directed upon a particular spot for any great length of time, but should move slightly so that the flame will come in contact with other parts in the immediate vicinity. This should not be understood to mean that the torch should sweep a circle whose diameter is one or two inches. Most beginners make this mistake.

The torch should be moved not more than ¼ or 5/16 of an inch at a time for average work—say ⅜" or ½" in thickness. A circular motion for metal of this thickness is not essential, but it is well to acquire it. For sheet metal work this circular movement is very desirable, producing a very smooth and pretty weld. However, there are some that prefer an oscillatory movement, the torch being pushed like a pendulum from one side of the sheet to the other while advancing in a forward direction. So far we have not referred to the welding rod. It should be held in the free hand. Instead of using a

straight rod, it will be found more convenient for the welder to use a rod having an angle of 90 degrees. In steel this is formed by simply bending over 3 or 4 inches of the end and continuing to do this as the rod is used up. For cast iron, we hold the end of one rod in the middle of another and "tack" the two with the torch. The size of the welding rod is important and should be proportional to the thickness of the metal welded.

The following table will be a fair guide to follow:

| Thickness of Metal No. 16 to 18 Gauge | Dia. of Weld'g Rod for Cast Iron | Dia. of Weld'g Rod for Steel No. 12 Gauge Wire |
|---|---|---|
| 1/8 in. to 1/4 in. | 1/8 in. | 1/8 in. |
| 1/4 in. to 5/16 in. | 3/16 in. | 5/32 in. |
| 3/8 in. to 1/2 in. | 3/16 in. | 3/16 in. |
| 1/2 in. to 5/8 in. | 1/4 in. | 1/4 in. |
| 5/8 in. to 3/4 in. | 5/16 in. | 1/4 in. |

Most beginners make the fatal mistake of not getting the metal to be welded hot enough before adding the filler rod. It is a good plan in beginning a weld to forget that you have a filler rod. Get the casting hot and then start the metal to flowing together *at the bottom* of the bevel. Not until then should the filler be used. The edges of the weld and the filler rod must

melt at the same time. If this is not done, the weld will be of no value.

The welding rod should not be held so that as the metal melts it falls in drops on the weld. In a great deal of work the welding rod is held against the welded portion practically at all times. Where this is not done, the rod is held so that the outer flame of the torch or the envelope will keep it hot, so that when the moment arrives for adding on some metal, the rod is lowered into the molten metal. By this time the end of the rod should be melting, but it may be necessary to direct the torch against the rod. A small amount of metal is added and then the edges of this added metal should be melted and made to intimately incorporate with the main body of metal. A very important thing to bear in mind is the distance the torch should be held from the metal. For steel welding the end of the white cone should just touch or brush the metal. For cast-iron it should not touch the metal but should be held about 3/16 of an inch from it. Sometimes, in order to work out blow-holes that are the result of impurities burning to a gas, it may be necessary to push the end of the white cone down into the molten metal and with a slight rotary motion flirt out the impurities.

# CHAPTER VI.

## Welding of Different Metals.

### CAST-IRON WELDING.

Probably 75% of the welding done in a custom repair shop is the welding of cast-iron. Contrary to popular belief, it is the easiest welding to learn, and when care and good workmanship are exercised the welded portion will be superior to the rest of the casting. The failures that occur are usually on pieces such as cast-iron boiler sections where the life of the metal has been burned out on account of long contact with a fire, or on work where expansion and contraction are difficult to take care of.

Cast-iron is an alloy of steel and carbon. The carbon contents vary from 3% to 5%, and it exists in two states: first, as a chemical mixture and, second, in a free state. In the latter case the carbon is distributed throughout the iron in much the same way that salt is placed in bread. Upon the amount of free carbon in the cast-iron will depend the softness of the metal and, of course, the ease with which it can be machined.

### HARD SPOTS.

The bugbear of the average beginner is hard spots in cast-iron welding. By ob-

serving a few rules this trouble can be practically overcome. The important rules to be remembered and observed are:

First, see that a neutral flame is maintained at all times.

Second, keep the white cone about ¼ of an inch from the metal.

Third, use a clean, high-grade welding rod, free from dirt and with a silicon content of about 3%.

Fourth, use only enough flux to make the metal flow and insist on a flux free from carbonates.

Fifth, cool the work slowly.

Even with all of these precautions followed, occasionally one will have a few hard spots. Usually these are on the surface and can be easily removed with an emery, but if any difficulty in doing this presents itself the following, which was recommended by an old blacksmith, may be tried: Place some powdered sulphur on the weld by means of an old hack saw blade or flat file and rub the sulphur on the weld until the suphur ceases to burn and becomes gummy; then cool slowly. While we know there are some objections to this, still it has been tried by the writer and while not infallible, it frequently helps.

It is necessary to weld cast-iron in a horizontal position. This is because it has

no tenacity when molten. Sometimes it becomes necessary to make a vertical weld, in which case a heavy piece of steel or a fire brick is used to form a shelf. As the welding progresses, the shelf is raised or built up higher. As previously stated, the edges of the metal at the weld should be beveled except for very thin metal.

Only first-class welding rods should be used. These should be purchased from those specializing in oxy-acetylene apparatus and who guarantee to flame-test their welding materials. It is to be deplored that at the present time there seems to be a tendency to buy on a price rather than a quality basis. It is the very poorest economy to buy cheap welding materials.

In using the flux, the welding rod is heated and dipped into the can when enough should adhere to the rod. If the iron is unusually "dirty," it may be found advisable to sprinkle some flux on the weld with the fingers, but too much should not be used.

Sometimes the operator has trouble preventing the metal from running away when trying to square up a casting. In cases of this kind, the torch should be turned over so that the flame will be pointed up. The force or blast of the flame will help to hold the metal and prevent its running

away. But this alone will not do. By watching the metal closely one can see when it is about ready to topple over and run down and just before this happens lift the torch and give the metal a chance to set. Then go back and add a few more drops and in a very short time enough metal has been added and the edge is squared up. All that is necessary is patience and practice.

### BLOW HOLES.

One source of considerable annoyance to the beginner is the formation of blow-holes in the weld. These could just as well be called gas holes, as they are caused either by the absorption of gases or by impurities in the metal burning to a gas, probably more often the latter. They will form with the good welder and the poor welder alike, but the difference lies in the fact that the good welder will get rid of the blow-holes, whereas the inexperienced permits them to remain in the weld. How does the good welder get rid of them?

Most beginners and also a great many who have had considerable experience get the surface of the casting flowing a little and then add a *heavy* layer of cast-iron from the filler and then attempt to "work in" this heavy addition. The mistake is

flowing in too much metal at one time. Not only on cast-iron, but on any kind of welding never add any more metal than is necessary. One should add a very thin layer at a time, putting it in the right place and leaving it there. A slight but constant motion of the filler rod and the torch should be maintained until the weld is finished. The filler rod should be dipped into the flux quite frequently and when a thin layer is added, lift the torch for a second or two and allow it to solidify before adding any more. By doing this, you allow to escape the gases which otherwise, as in case of a heavy addition of filler, are covered over and enclosed and are unable to break through the heavy layer of metal.

In the making of bread, lightness is desired. This lightness or porosity is obtained by the formation of gas, and its retention in the bread until baked or solidified, producing a multiplicity of blow-holes. If for any reason the gas escapes, the bread drops, becomes heavy and compact, something to be regretted in bakeries, but the very thing we are trying to do with the cast-iron—allow the gas to escape so that it will be compact, close-grained and free from blow-holes.

In welding of large castings that have had to be pre-heated, or even those the

size of automobile cylinders, the work is attended with considerable discomfort on account of the heat. We would recommend the use of a portable electric fan. This can be set on a box and pointed so that the blast of air is in an upward direction, just in front of the welder. It is needless to say that the current of air should be turned so that it will not strike the casting. By using a fan the operator will at all times be supplied with fresh air free from any fumes and will be kept cool, a condition that enables him to turn out more work than otherwise. It is not only humane, but it will be found to be good business practice to furnish a fan.

### WELDING OF STEEL.

For the average welder, steel may be divided into two classes—soft steels and hard steels. The difference between these two is mainly that of carbon content. In the soft steels the carbon content may be as low as .05 per cent, while extremely hard steels may contain as much as 1.5 per cent of carbon. Low carbon or soft steels have high ductility and malleability.

Increasing the carbon contents increases the strength, elastic limit and the property of being hardened by tempering. The soft steels are the easiest welded, while the

hard steels, particularly if the metal is over one inch in thickness, are the most difficult. Operators quickly learn to do beautiful work on thin sheets of soft steels, but they are lost when attempting heavy work. Unquestionably the welding of medium and heavy steel is the most difficult to learn.

The average welder does not get his metal hot enough or he gets it too hot and burns it or oxidizes it, as the chemist would say. Of course, it is a comparatively easy matter to overcome the first shortcoming by increasing the size of the welding flame or by playing the flame on the metal for a longer time, but the second fault of burning the metal is not so easy to avoid. It is practically impossible to prevent this, using a torch of poor design supplying an excess of oxygen to the flame. We have already emphasized the importance of using scientifically designed torches, but it will bear repetition. As oxygen is always present in the air, this atmospheric oxygen will greedily attack the steel when in a heated condition. All of us are familiar with the scale that forms on steel when heated in an open fire. This scale is simply oxidized iron or burnt metal. If this oxide is allowed to incorporate itself with the weld, the strength is bound to suffer.

It would almost seem superfluous to again impress upon the beginner the importance of flame regulation, did not necessity demand it. An excess of acetylene carbonizes the metal, while an excess of oxygen burns it.

The importance of using a good welding wire is usually underestimated. Swedish wire has long been advocated and it is excellent, but we doubt at the present time whether there is any genuine wire of this kind in this country. This does not mean that excellent domestic welding wire is not to be had. On the contrary our country produces as fine welding wire as any nation. The impression prevailed for a long time that Swedish iron's reputation was based on the fact that it was made with high-grade charcoal, but recent investigations have exploded this belief. We know now that the strength and tenacity of Swedish iron is due to the fact that centuries ago Mother Nature deposited with the iron ore a small percentage of vanadium, and when the ore was smelted, this vanadium, scavenger like, cleansed the metal of its impurities and thereby imparted those properties which have given it its reputation.

Some American firms, grasping at anything that will help them to dispose of their

wares easily, have coined trade names in which a part of the name Sweden is used, by which they designate their wire. On the face of it, it is designed to deceive and mislead the public.

Acting on the knowledge we have as to the properties of vanadium, several years ago the writer, in conjunction with one of the large steel companies, experimented and finally produced a rod containing a low percentage of vanadium and carbon which for heavy welding is unsurpassed. It must be remembered that there are many kinds of vanadium steel on the market and only one kind is suitable for a filler rod.

There are some writers who advocate the hammering of the metal after welding. This probably does do some good if the operator is able to determine the correct temperature at which the metal should be and is capable of maintaining this temperature, otherwise more harm than good will be done.

The exact temperature at which hammering should be done is difficult for the novice to either determine or obtain, and our advice is to learn to rely upon the welding alone.

The welding of hard steels is difficult even for an experienced welder and the beginner had better not try this class of

work. The work is best done if the entire piece or at least a considerable portion of it is pre-heated to a cherry red and a tip selected that is one size larger than if the work was soft steel. If anything, the flame should be slightly carbonizing. The welding should be done fast. One should not linger over the work, as this will burn the metal.

### WELDING OF BRASS OR BRONZE.

Brass is an alloy of copper and zinc, while bronze is an alloy of copper and tin. With the exception of the cheap brasses, that is, those having a high percentage of zinc, either brass or bronze can be welded with good success. When hot, considerable care should be exercised, if it is necessary to move the work, as neither one of the two alloys has much strength then and the least strain will cause the casting to break.

The work should be beveled and the edges and immediate vicinity of the weld thoroughly cleaned.

A welding tip one size larger than is necessary for the same size work in cast-iron should be employed. Pre-heating is justified on the grounds of economy. The white cone should be held a distance of about ¼" from the metal. Just back of the weld on both sides should be heated

thoroughly, and some flux sprinkled in the groove. The torch is then switched to the beveled edges and as the edges commence to melt add the filler rod of either Tobin or manganese bronze, first dipping the heated rod in the flux. If the weld is a tooth in a gear or located at some wearing point, manganese bronze is preferable as it is somewhat harder, otherwise use Tobin bronze.

Weld fast or you will find blow-holes in your work due to the zinc and tin burning out and the metal absorbing gases.

### WELDING OF COPPER.

The melting point of copper is not only high, but it also conducts the heat very rapidly and these two properties combine to make it a metal very difficult to weld properly. In addition it absorbs gases from the welding flame, which causes the formation of blow-holes.

The metal should be cleaned in the immediate vicinity of the weld and the edges to be welded should be beveled. A welding tip one size larger than is required for the same thickness of cast-iron should be used. On account of the high conductivity, it becomes necessary to pre-heat a considerable area in the vicinity of the weld to a high temperature before starting to weld.

A neutral flame should be maintained and the white cone should be held about ¼ of an inch from the metal. A flux should be used. While a pure copper rod is much used, better results can be obtained with a special rod containing a very slight percentage of phosphorus.

### WELDING OF ALUMINUM.

Of late years, aluminum has come into such common use that everyone is familiar with it. When heated to a high temperature it becomes very fragile, not having sufficient strength to hold up its own weight. Like copper, its conductivity is high. Its tendency to oxidize is greater than that of any other commercial metal.

When the metal is heated to the melting point, this oxide is easily seen and by the workman is usually spoken of as the "skin."

The piece to be welded is prepared in much the same manner as though it were cast-iron or brass. The piece is cleaned and the edges are beveled. For the beginner we have one suggestion to make which he will find of considerable assistance, but which he may possibly discard after he becomes proficient. We have already stated that the metal has no strength when it is around the melting point and the be-

ginner will very likely find his work sinking in or holes dropping through it.

When this happens a few times the operator is apt to become "rattled" and discouraged. To avoid this happening one can prepare the work as follows:

After the work has been cleaned and beveled, wet some paper and lay over the crack on the underside. Take a wire and form a slight loop. Fasten one end to the casting on one side of the crack and the other end to a part of the casting on the other side of the crack. Take some plaster of Paris and add sufficient water until it is of a thick consistency and then put it on top of the wet paper and around that part of the casting where the crack is located. The wire mentioned above will act as an anchor to hold the plaster of Paris and prevent its falling out. The plaster must then be allowed to dry. When it has done so, a perfect supporting mould will have been formed. The wet paper has prevented any of the plaster from getting into the crack. We can now proceed to weld without the danger of the casting dropping in the event it should happen to get a little too hot.

The average beginner is apt to consider aluminum welding as very difficult. This is not the case when one understands the

nature of the metal and also keeps in mind the principles of expansion and contraction.

Compared with cast-iron, what do we find? That it melts at a very much lower point and yet conducts heat very much more. When heated, its expansion is greater and, of course, when cooling its contraction is greater than cast-iron. This means that the portion that is brought to a molten state by the flame will, when cool, occupy less space than will cast-iron under the same operation. The oxide or "skin" already mentioned requires about twice as much heat to melt it as does the metal. A little reflection and we see that some external means must be resorted to in order to destroy or remove this oxide before a successful weld can be obtained.

There are three methods of doing this. Each is good when properly executed. They are:

First, welding by puddling.

Second, welding with a flux.

Third, combining these two methods by puddling while at the same time using a flux.

The puddling method was the first in vogue and is still used quite extensively. It consists in removing the oxide mechanically by means of a rod, called a spoon.

Two spoons are employed and they are very simple, consisting of two ¼" steel rods, each flattened at one end and one of them being bent at a right angle. The right angle spoon is used to scrape out the weld, while the straight spoon is for working into shape the new material that has been added into the weld.

In practice an operator starts heating the metal and when he thinks it is about the melting point he tries it with the right angle spoon. If it is, the skin or oxide and any dirt that may be present is carefully scraped out for a distance of an inch or two. The spoon is then dropped and the filler rod is quickly taken up and material added.

The straight spoon is then substituted for the filler and the metal is worked and shaped. When this is finished another inch or two is started and continued until the entire crack is welded.

Welding aluminum by means of a flux is a more recent method. The aluminum is heated to the melting point, as is likewise the filler rod, when the latter is dipped into the flux and is then brought into contact with the molten metal at the weld. When the weld is cold, the flux should be washed off with water and a brush.

Either of these methods is good. The

first has the advantage of looks, while the latter that of speed; the strength of each is about the same. The third method is rather fancied by the writer for repair work. It is really a combining of the two above-mentioned methods.

The spoon is used to clean out the weld. The flux method is then used, and when a few inches of welding is done, we revert back to the puddling method and use the flat spoon for shaping and finishing up the work.

### WELDING MALLEABLE IRON.

Malleable iron is practically cast-iron that has been annealed. If it is a thin casting this heat treatment tends to transform the entire piece into a semi-steel, but if the casting is fairly thick we may expect only the outer portion to have been affected.

Beginners usually experience considerable difficulty in detecting a piece of malleable. Occasionally an experienced man will be fooled. If the casting is not very thick the color of the metal at the break will be white in the center with a very narrow dark ring around the outside. If the casting is fairly thick, the center portion will appear cindery. When the torch is applied it is comparatively easy to recognize it. When first heated it sparks a little, so that you know it is not cast-iron. When

it commences to melt, blow-holes invariably form. Some still cling to the notion that it can be successfully welded with steel or with cast-iron. This is not true. Whenever steel or cast-iron is used on malleable it shows a lack of knowledge of the business. Whenever it becomes necessary to melt malleable iron, upon cooling it will be converted into a very poor grade of cast-iron.

The only successful method of joining two broken pieces of malleable is by brazing. This has been proven to be entirely satisfactory from a standpoint of strength, if the work is properly carried out. The work should be cleaned and beveled. Tobin bronze or high-grade brazing wire is used in conjunction with a flux. The malleable iron should not be heated to the melting point, a bright red or at the most a white heat being employed. To start the braze, the writer prefers the use of spelter, which in this part of the country is the name for fine particles of brass mixed with a flux. This is sprinkled on the beveled edges and coats the edges with a thin layer of brass. We then take the Tobin bronze rod and finish by using it as filler, using it rapidly.

### WELDING OF LEAD OR LEAD BURNING.

Lead burning, as it is commonly called,

is really the first form of autogenous welding. As the melting point is low, a tip which gives an exceedingly small flame is used. The edges to be welded should be cleaned and scraped until bright. Since the electric starter and electric lights are almost universally used on automobiles, a lead burning outfit is now almost a necessity for the garage in the repair of batteries.

While excellent work is done with oxy-acetylene, ordinary coal gas and oxygen is used with splendid results. In some cases the coal gas is compressed into tanks, but in the majority of cases a special designed torch is used which permits of taking the coal gas direct from the city main at a pressure of only a few ounces. Very little skill is required for average work. Ordinary clean lead cut into strips from a sheet or just scraps is used as a filler.

For lead burning of chemical tanks or containers it is sometimes necessary to do vertical work. This requires considerable practice. It may be well to state, however, that a vertical weld is never so good as a horizontal one and the natural inference is that whenever it is possible in work of this character, the tank should be laid on its side so that the work can be done in a horizontal position.

# CHAPTER VII.

## Welding of Sheet Metal and Pipe.

### WELDING OF SHEET IRON.

For the welding of very thin sheet iron, say from No. 22 gauge to No. 28 gauge, it is rather difficult to make a butt weld, for the reason that almost as soon as the metal is in a molten state, a hole has burned

Fig. 17.

This shows a butt weld, with edges beveled on one side. For metal of ⅛ inch in thickness or less it is not necessary or desirable to bevel. The dotted line indicates the metal which has been added from the filler rod.

through which is difficult to patch. It will be found best to turn up the edges so that a flange of as low a height as possible is secured. Clamps should be used to hold the metal even and the flange should be

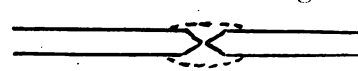

Fig. 18.

This shows a butt weld on metal ½ inch in thickness or more. In this case the bevel is from both sides. This is desirable if both sides are accessible.

"spotted" or "tacked" at intervals of about four or five inches. No filler rod is used, as the flanges upon being melted down

supply the necessary material. Some knowledge of sheet iron work is necessary in order to properly make the flange.

For sheet iron of slightly greater thickness, say Nos. 12, 14, 16, 18 and 20 gauge, the welds can be made in several ways. It can be done by means of a flange as indicated above for very light metal; it can be butt welded either with or without a filler rod or it can be welded with a flange differing somewhat from that mentioned above.

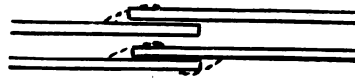

Fig. 19.

This illustrates two lap-welded joints, one in which the weld is made only from one side and the other where it was made from both sides. Ordinarily this is not a desirable way to make a weld with the torch, but occasion will sometimes demand it.

The above applies to the welding of irregular shapes and small articles. If the welding is on sheets formed as tanks or containers, and the task is a quantity proposition, more detailed information is necessary. As previously stated, when welding No. 20 gauge metal or higher it is better to flange the edge. On this light metal it is difficult to make the flange correctly; in fact, it cannot be done in a machine, owing to a tendency of the metal to

draw. The most satisfactory method is to tightly fasten the sheet in a clamp, allowing about 1/32 of an inch to extend beyond the clamps, and then turn the flanges with a coarse file. This flange will be at an angle of about 45 degrees, but as the metal increases in thickness the flange will be straighter until in No. 16 gauge and heavier it will be almost at a right angle, and it will be found to be easier to make.

Fig. 20.

This shows sheet metal flanged preparatory to welding and also the appearance of the sheet after the weld has been executed. It is to be noted that in the illustration the height of the flange is little more than the thickness of the metal. When edges are prepared in this manner, the molten metal of the flange flows onto and incorporates with the metal of the sheet beyond the knuckle of the flange. In some cases the flange is made quite high—from ¼" to ¾"—and of course just the edges are melted together.

For flanging No. 20 gauge and heavier an old press, working on the same principle as a square shear, can be utilized. It will have one sharp and one dull die; the dull one being on top and the sharp one on the bottom. As the dull die comes down it forms the edge or flange. The top or dull die is set back, leaving a gap, the width of which is equal to the thickness of the metal. As an example, for No.

16 gauge metal, it would be set back 1/16 of an inch. Welds made with the metal formed in this manner are to be preferred to a butt weld even with a filler added, as the weld is made faster, it is stronger as considerably more metal of the same stock is in the weld and in numerous tests made with the same metal, operator, etc., where all factors were the same, there were less leakers.

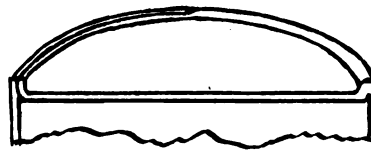

Fig. 21.

This shows one method of welding in the heads or bottoms of round tanks made from light stock. The edge of the head is flanged and the two edges are fused together.

Regardless as to whether the weld is a flange or butt, it is advisable to have clamps or what the trade calls stakes, for holding the edges.

Usually an old railroad rail is utilized for the mandrel portion of the stake. The ball or top is machined so that the sheets will be level. In the middle of the top a longitudinal slot is cut about ½-inch wide and ¼-inch deep. The edges of the sheet are placed directly over this slot, its object

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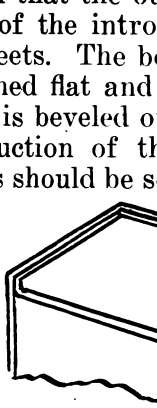

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the thickness of the metal and the speed of the operator. No hard and fast rule can be given, but for a tank 34 inches long made of No. 16 gauge metal it is usually spread ¼ of an inch and for No. 18 gauge metal the same length, it is spread about 3/16 of an inch.

Fig. 23.

This shows a dished and flanged head of a round receptacle in position and partly welded. If the tank is under only a slight pressure the weld can be made at the knuckle of the flange. If the tank is for high pressure the weld should be made farther down and nearer the edge of the flange.

Some writers have fixed 2½% of the running length of the weld as the distance the sheet should be spread, but this is often erroneous. As the weld progresses, the sheets come together.

### WELDING OF CONNECTIONS.

In almost all containers, one or more connections are necessary. A pipe nipple is used, and for the sake of economy is usually cut in two in the middle, thus making two. It is then put in a lathe and a cut taken on the inside threaded portion, leaving a shoulder about ⅛ of an inch thick and 3/16

of an inch high. The hole in the tank is flanged out and when in position for welding we have the edge of the sheet and the thin edge or shoulder on the nipple adjacent. No filler is used. The two edges are simply melted down and an entirely satisfactory connection is made. (Fig. 27.)

Fig. 24.

This shows a dished head without a flange in position and partly welded. This method is not recommended where the container is subjected to high pressures.

## MACHINE WELDING OF SHEET METAL.

Machine welding can be employed in the manufacture of certain articles made from rather thin sheet metal. Naturally, in order to be practical, it must be a repeat or quantity proposition. These machines are either automatic or semi-automatic. For pipe of small diameter, wind shield frames, etc., the metal is of thin gauge and the operation consists of an autogenous butt weld in combination with pressure. This last is important. The two edges to be welded are mechanically brought together so that they are even and in perfect alignment, and at the instant the oxy-acetylene flame produces fusion of the

metal on top, rollers or shives engage both sides of the tube, pressing or squeezing the molten edges together. In practice the tube or frame is formed and welded in one operation. The work and not the torch moves. Strips of sheet metal are cut as long as desired, care being taken that the cut is

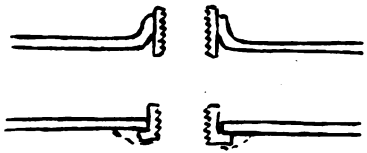


Fig. 25.

This shows two ways of welding fittings or connections in tanks.

even and the width of the sheet the same throughout. It is then formed by being drawn through dies, the position of the two edges being on top so that they will come under the flame. As the tube progresses towards the torch it is guided by several pairs of shives or rollers, one set of which is located at a point where the flame touches the metal.

The object of this particular set of shives is twofold, first to guide the tube and second to press in on the sides and squeeze the metal together. Other sets of shives may be arranged behind the flame to straighten the tube should there be a ten-

dency towards distortion. At the present time no real success has been obtained in an effort to automatically butt weld thin sheets when the diameter of the cylinder was in excess of 12 inches. On the other hand, the automatic welding of thin sheets is entirely practical, regardless as to the diameter, if the edges are flanged. This is comparatively simple whether the vessel is cylindrical or square. Sometimes the flanges are tacked by hand at two or three

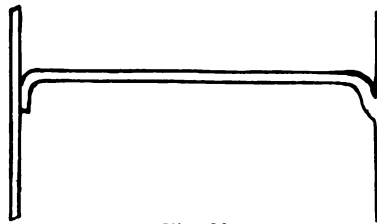


Fig. 26.

For divisions in tanks or where top or bottom is required to be set in from end this illustrates a very good way. The weld should be made on the flange near the knuckle.

points before the actual welding begins. In this case, the torch and not the work travels. The torch is screw driven and some experimenting is necessary in order to determine the size tip necessary, the angle it should take, and the speed it should travel. For boxes and some cylinders no clamping or supporting devices are neces-

sary. It is necessary to provide some means for forcing together the two edges of the flange immediately in front of the flame. In some cases this is done by means of a set of rollers that immediately precede the flame, traveling automatically with the torch; in others this is done by an operator using a pair of pliers that is provided with a couple of small rollers.

Most automatic machines are limited as to the scope of work which they will accomplish, but for the particular duty for which they are designed they will do beautiful, strong, rapid and cheap work.

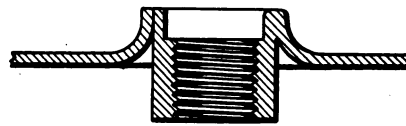


Fig. 27.

In some instances it is advisable to use a water-cooled tip, but for most work this is not necessary. The necessity for a water-cooled tip is greater where low pressure acetylene is used, in view of the fact that a considerable variance in the flame of a low pressure torch is noted upon the tip becoming heated. On the other hand, where high pressure acetylene is used, more attention must be given to the regulators to see that they are operating accurately.

## WELDING OF GAS, AMMONIA, AIR, STEAM AND WATER PIPES AND MAINS.

During the past two years, the oxy-acetylene torch has been used quite extensively for the welding of pipes and mains.

Fig. 28.
This shows special joint on gas main made by welding.

In the West, in some instances, hundreds of miles of pipe have been laid without a threaded connection, while in many cities this class of welding has reached considerable proportions. It has been demonstrated that the strength of the weld can easily be made greater than that of an unwelded pipe and the cost of the welded connection is less than the cost of the screwed connection. There is also no danger of leakage. Where pipe is welded a much lighter wall is permissible, as no allowance need be made in its thickness for threading. This permits of a considerable saving and at least one company is now

advertising a pipe having extra thin walls for welding. By specifying, the mills will furnish the pipe with the ends beveled at no extra cost. In practice the work is done as follows:

Fig. 29.

This shows special "Y" joint on gas mains made by welding.

The pipe is laid end to end on top of the ground. If the ground is uneven it is best that they be supported by 2x4's in order that they can be easily turned. If the pipes are cut at a bevel, the ends are butted together. If, however, the pipes are cut off straight a space of from 1/16 to

¼-inch is allowed according to the size of the pipe. In addition to the welder, two helpers are furnished. They are stationed one at each end of the section and their

Fig. 30.

This shows reducer made on gas main by welding; flange is also welded on to pipe.

duty is to turn the pipe with tongs as the welding progresses, always permitting the operator to weld on top of the pipe, as greater speed can be made. The pipe

should be turned towards the welder. Hose of sufficient length should be provided so

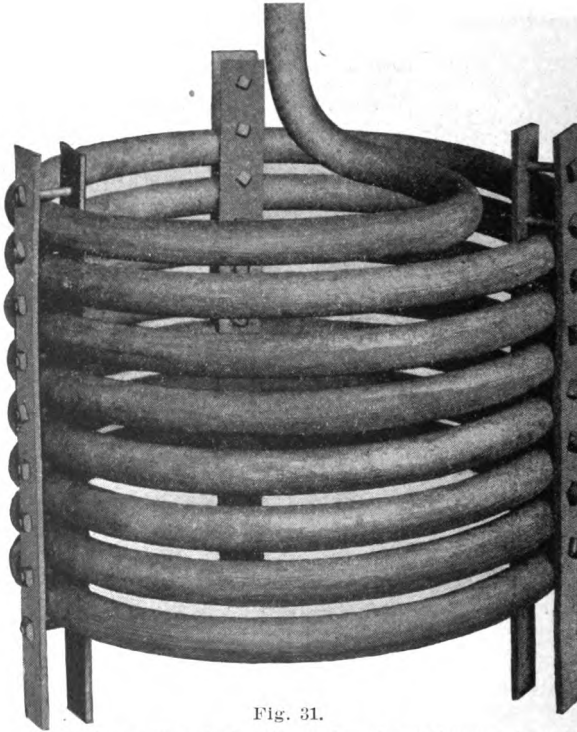


Fig. 31.

This shows a spiral coil made of continuous lengths of pipe, homogeneously welded and bent into shape. These coils are used in refrigerating systems.

that he may weld from either side of the pipe. Ordinarily, pipe comes in about 20-

foot lengths, but for welding purposes it can be procured in 40-foot lengths, thereby reducing the connections. In cities, the number of lengths that can be welded to-

Fig. 32.

This shows 37 feet of pipe, originally in two pieces but welded together in the center and bent to form an expansion loop. The weld can be seen just above the crane hook.

gether is usually limited by the length of the blocks, but in the country quite frequently lengths of 1000 feet or more are

welded together before rolling into the trench.

The welding of two sections in the trench is more difficult. This weld must of necessity be a stationary one, so a pit must be dug of sufficient size to permit the operator

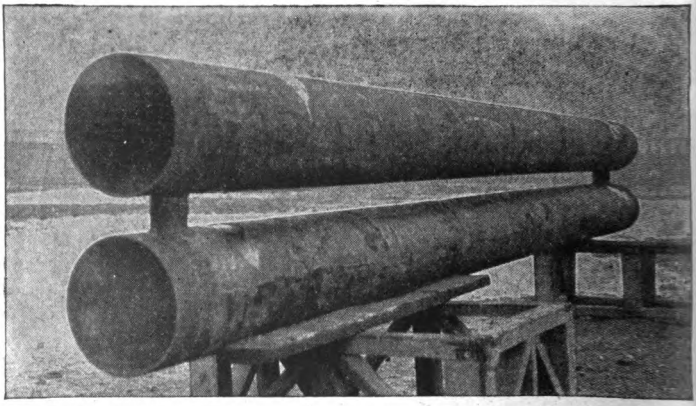


Fig. 33.

This shows a welded drip composed of 16-inch pipe. This not only makes a better job but on this drip there was a saving of $450.00 over the old method.
—Courtesy of National Tube Company.

to work on both sides and under the pipe. The welding at this connection consists of ¼ horizontal, ½ vertical and ¼ overhead, but with practice this is easily accomplished. It follows that all sorts of tees, angles, reducers and connections can be welded.

It may be of interest to give the result of some tests showing the relative strength of welded and screwed pipe connections.

| Pipe Size Dia. | Welded Connection | Screwed Connection |
|---|---|---|
| ½ in. | 12250 pounds | 8560 pounds |
| ¾ in. | 21276 pounds | 12640 pounds |
| 1 in. | 29810 pounds | 17560 pounds |
| 1½ in. | 44120 pounds | 31440 pounds |

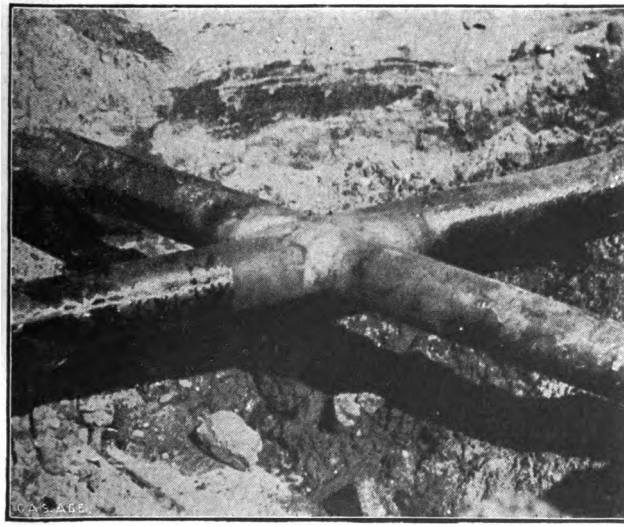


Fig. 34.

This gives some idea of the appearance of a cross in an 8 inch main when welded.

The cost of welding depends upon the skill of the welder, the efficiency of the apparatus and also upon local conditions.

If not delayed too much in moving from one point to another, a competent man will weld as follows:

10 to 12 joints of 2 inch pipe per hour
5 to 6 joints of 3 inch pipe per hour
3 to 4 joints of 4 inch pipe per hour
2 to 3 joints of 6 inch pipe per hour
1 joint of 8 inch pipe in about 40 min.
1 joint of 12 inch pipe in about 1 hour.

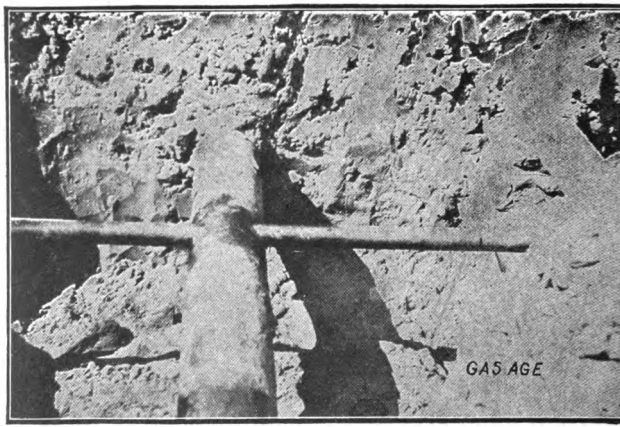



Fig. 35.

This shows a 3 inch lateral welded to an 8 inch main; a simple operation for the Oxy-acetylene torch.

A comparison of the cost of joints of different size welded and with threaded couplings follows:

| Size of Pipe | ½″ | ¾″ | 1″ | 1½″ | 2″ | 3″ | 4″ |
|---|---|---|---|---|---|---|---|
| Butt Welded Joints. | $0.03 | .04 | .05 | .07 | .10 | .18 | .30 |
| Threaded Couplings | $ .04 | .05 | .07 | .11 | .15 | .32 | .52 |

Attention is directed to the fact that as the pipe sizes increase, the advantage of a lower cost for the welded joint is very much greater.

It follows that the welding of steam, air and water pipes in industrial plants, railroad shops, yards, etc., is entirely feasible and in a great many instances preferable to threaded connections. As an example, the Terminal Railroad Association of St. Louis have welded all of the pipes running through their yards. The St. Louis Refrigerating & Cold Storage Company welded a great many miles of their street ammonia pipes and the results are so satisfactory that they are replacing the screwed connections with welded joints as rapidly as possible.

# CHAPTER VIII.

## Welding of Various Pieces.

### WELDING OF BOILERS.

Probably in no field of welding has advancement been faster or the application greater than in the repair of boilers. Cracks, patches and entire sheets are now welded with complete success. Naturally, there are various ways of doing this welding, and it follows that practical men will frequently conscientiously differ as to which method is the best. It is the desire of the author to give to you at least one way of doing the work well. If you can improve over it, so much the better.

The first job we will discuss is the welding of a half side sheet in a locomotive fire box. With the exception of the side which is to be welded the new sheet is prepared exactly as though it were to be riveted in. When possible, all stay bolts should be put in, with the exception of a row on each side of the weld. The mud ring and the door and flue sheets can be riveted in, leaving two or three rivets on each side of the weld so that the flange can be raised up to allow the sheet to be welded underneath.

If the front and flue sheets are old ones

this can be omitted and the flange welded to the side sheet for six or more inches each way. The rivets should be put in after welding. While it is usually more convenient to put in at one time all of the stay bolts and rivets, with the exceptions noted above, it is not necessary, and it can be dispensed with, excepting one row of stay bolts which hold the edges together. No bad effects will follow, the sheet will not draw up a bit and the rivet holes in the mud ring and the stay bolt holes will line up perfectly. Of course, the edges of the new and the old sheet where the weld is to be made are beveled so that they form an angle of 90 degrees. A space or opening about ¼″ wide is allowed between the two sheets. The new sheet is cut to allow for this, if not a ripping tool is used to provide it. When the sheet is properly fitted the welding is begun. It will now be necessary to refer to Fig. 36, which represents a side sheet ready for welding. The edge next to and under the flange No. 1 is first welded. We then move ahead about ten inches to No. 2 and weld back to No. 1, then go to No. 3 and weld back to No. 2 and so on across the sheet. It is sometimes necessary to have a pinch bar to pull the edges in line; otherwise, there will be no trouble with the welding.

Dozens of sheets have been welded in this way without any trouble, except in the case of a green man who was not able to make a weld. One advantage is, the welder can stop at any time without any trouble.

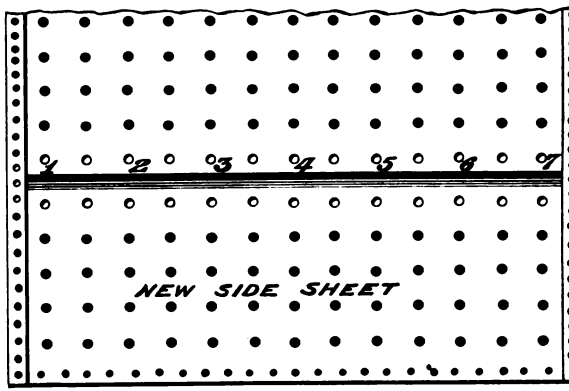



Fig. 36.

There are two other methods used in welding in side sheets, which the writer does not like so well, but which are used by others with from fair to good results.

The first consists in dropping one end of the sheet about 2% of the running length. This was perhaps the first method used in this country and some still cling to it. If the sheet is dropped the correct distance, it will pull up into place as the weld-

ing progresses. The trouble, however, is due to the fact that there can be no fixed rule for determining how much the sheet should be dropped for each individual welder. The reason is that this distance which the sheet is dropped is determined to a very considerable extent by the speed of the welder, and no two men weld at the same speed.

The other method consists in putting in the new sheet as though it were to be riveted. The stay bolts are put in except the two or three rows at the top near the line of the weld. Bolts are put through the outer sheet and forced against the new sheet. This shoves the new sheet away from the line of the weld. Another bolt is nearer the edge to be welded and it extends to the outer sheet. An assistant on the outside tightens this bolt and pulls the new sheet back into position. By doing this a corrugation or hump is produced in the new sheet just below the line of the weld. The welding can progress from either end, and as it does the bolts should be released, with the result that the contraction pulls the corrugation out, leaving the sheet straight and in good shape.

### WELDING OF A SIMPLE CRACK.

The crack is prepared by being beveled

to the usual 90 degree angle. A ⅛-inch to ¼-inch opening is made at the bottom, depending upon the length of the crack. Before welding, heat in the line of the weld for several inches at the ends of the crack. This is done to expand the solid sheet and open the crack. If the crack is a short one of only a few inches, start at one end and finish up at the other and then heat a few inches beyond.

If the crack is a long one, say 18 inches or more, instead of starting at the end, begin about 8 inches from the end, and weld back in exactly the same manner as indicated for welding in a side sheet.

### WELDING OF A PATCH.

In the welding of patches, it is preferable to use a triangular patch, with the corners slightly rounding, say about one inch radius. With this shape of patch there can be no parallel welds as is necessary with any other shape, and this is to be desired; also there are only three sides or legs to weld. Each leg of the patch should be straight. The bad place is cut out with the cutting torch and the patch fitted in, first being prepared by beveling, etc., the same as was done in the case of the side sheet and the crack.

By referring to Figs. 37 and 38, the man-

ner in which the weld is made will be easier understood.

In Fig. 37, we show a patch in the form of a right angle triangle and in Fig. 38 the patch is an equilateral triangle. The welding differs little in either. The welding is started at No. 2 and the weld is made towards No. 1, then we go to No. 3 and weld to No. 2 and from No. 4 to No. 3.

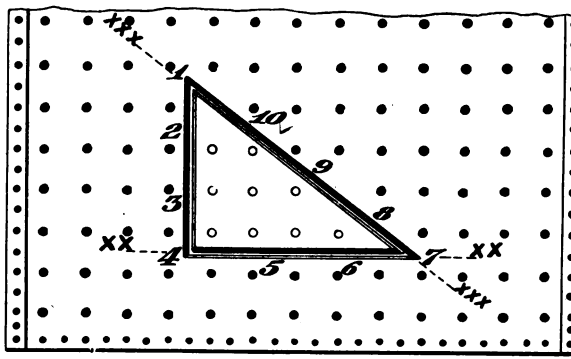



Fig. 37.

It is then preferable to allow the weld to cool down, and then before starting welding heat in the line of the weld No. 4 to No. 7 for about 6 inches at each end, as shown by XX. Then start welding at No. 5 and weld to No. 4, jump to No. 6 and weld to No. 5 and finish this leg with a weld from No. 7 to No. 6. Then let this weld

cool and before starting on the final leg heat in the line of the weld No. 7 to No. 1 for about 6 inches as shown by XXX. In making this final weld it is better, if possible, to start at No. 10 and weld to No. 1, then at No. 9 and weld to No. 10 and so on until completed. By doing this the weld is made upwards, which is faster and easier. Of course, conditions are sometimes such that this is not desirable. It is simply a matter of convenience.

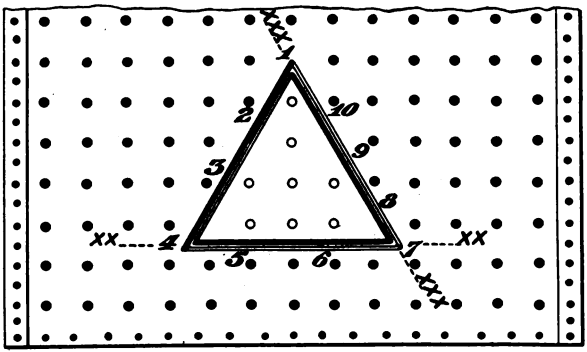



Fig. 38.

There are some who use a dished patch and others one with the edges corrugated. Undoubtedly patches made in this manner are at times of assistance to the welder, but the writer is strongly of the opinion that this is not necessary if the welding is done

properly. An examination of a number of welds that proved defective, showed conclusively in nearly every instance that either the welding or the judgment was poor, or both. Any boiler sheet should stand the shrinkage of one welded seam and if that weld is allowed to cool before the next weld is made there will only be the shrinkage of one weld to consider when the last weld is made. There should be very little strain in a weld when cold. Whenever a weld cracks immediately after welding while it is still hot, an indication that the weld is poorly made, it will be found that the crack opens widely, sometimes as much as ⅛ of an inch.

If the weld is properly made and it should crack, which will only happen after it becomes cold, it will be found to show as a very faint line. This shows that in cooling the metal in the good weld stretched considerably, whereas in the poor weld there was not sufficient strength to permit of the metal stretching.

### WELDING CRACKS IN THE THROAT SHEET OF BOILER.

Cracks often form at the throat sheet. They usually begin at the water side. A great many consider it impossible to successfully weld cracks of this kind, and yet

the writer knows thoroughly competent operators who are doing this with entire satisfaction. The work must be carefully done and the weld reinforced for about one inch on both sides of the line of the weld and beyond the end of the crack, and when finished, heated in the same line for some distance each end of the weld. Where possible the weld should be made on both the water side and the outside, but one side alone will do.

### WELDING OF AUTOMOBILE CYLINDER.

The welding of an ordinary crack in the water jacket of an automobile cylinder is not a difficult task if one has a fair knowledge of welding and carries out to the letter instructions as to pre-heating. The cylinder should always be stripped, and if possible educate your customers to bringing them to the shop in this condition. Valves, springs, pet-cocks, etc., should all be removed. The cylinder should be carefully examined in a good light to determine if possible whether there are any cracks other than those which are easily seen. Sometimes, when considerable care is exercised, but frequently through carelessness, the operator overlooks a crack and has to reweld the cylinder. The cracks should be chipped to a 45-degree angle with a diamond

point. This not only insures a better weld, but when this is done one is very much more apt to detect stray cracks If the cylinder is painted, this should be removed for about an inch on both sides of the weld by means of an old file. Some graphite should be obtained and mixed with kerosene until it is of a thick, pasty consistency. This should be rubbed on the inside of the cylinders and on the valve seats and also on the threads of the valve chambers by means of a swab, which is simply made by tying some rags or waste on the end of an iron rod. This may seem unnecessary to some, but it certainly will protect those parts which are covered with it, and their appearance after the welding is finished will be better. This will please the customer, and the writer believes you cannot be far wrong when you do that.

The cylinder is now ready for pre-heating. Place it with the valve parts down and the open end of the cylinder up. Do not lay it on its side. Usually there is an abundance of old scrap asbestos around a welding shop, and some think it advisable to fill the cylinder with this. Certainly it can do no harm, and it may do good. Enclose the cylinder on all sides with fire brick; this makes a temporary furnace. If charcoal is used it should be lighted and

allowed to burn of itself. No forced draft should ever be employed. Remember that what is desired is an even heat, and this is best obtained by slow heating. If coal gas is employed, a torch using atmospheric air should be used, and the flame made to impinge on the brick—not on the cylinder. A piece of sheet iron or asbestos paper is laid on top of the brick furnace to keep out any drafts. Some use a metal hood, counter-weighted, which will cover the entire furnace. Occasionally the cylinder should be examined as to its condition. The degree to which it should be heated is one of the things on which there is a difference of opinion.

Some heat to a point where it is just too hot to lay your hand on, others heat to a dull red, while there are some who raise the temperature still higher. The writer's experience would justify his advising almost a dull red heat. The cylinder should then be turned in a position for welding. If charcoal is used it is left in the fire; if coal gas the torch is either turned low or extinguished altogether. For turning or moving the cylinder, a small chain block with an old pair of ice tongs will be found very convenient, eliminating in many instances the need of a helper. The welding should then be done. If it is a

long crack or several, requiring considerable time, it is best to stop before completion and reheat by the addition of more charcoal or by turning on the gas torches. When finished, again turn on the gas torches for a while or replenish the charcoal, cover well and let it cool slowly.

In justice to yourself and your customer, always test the cylinder under water pressure before sending it out. For doing this quickly a number of wooden plugs of different sizes should always be kept on hand for closing openings for which you will probably have no plugs. If you have a water system, connect the water line with one opening and turn on the pressure. If not, fill with water and use a hand pump, raising the pressure to 15 or 20 pounds.

### WELDING OF A LUG ON A MANIFOLD OR A CYLINDER

Anyone familiar with either casting will know that their faces are machined and, therefore, true. Naturally, it is desirable that this alignment be maintained when welding on a lug that has been broken off.

If one possesses a face plate or a straight edge, the manifold or the cylinder can be clamped to it, first placing underneath two or three thicknesses of ordinary paper. Place the broken lug in position and either

clamp it down or hold in place with a two or three-pound weight. Do not use any paper under the broken lug. By doing this, the lug will be slightly lower than the remainder of the casting and this will allow for the pull or shrinkage in the metal. Tack the weld at one side and then start at the other side and weld around to where the "tack" was made. The clamps should then be removed and the casting turned over and the weld touched up from this side. After the weld is finished, cover with asbestos and allow to cool. If there should be a slight excess of metal on the machined side it can easily be filed off.

### REPAIRING A SCORED CYLINDER.

Frequently a wrist pin works loose, with the result that the friction wears a slot almost the entire length of the cylinder. This means loss of compression, and if the score is very deep, very little power will be obtained from that cylinder. To repair this by welding is not an easy undertaking. When the welding is completed, of course it is necessary to regrind the cylinder. This is not objectionable, but in the majority of cases it is necessary to regrind until the cylinder is enlarged, which means an oversize piston must be used. In addition to this added expense

there are other objections, so that we would advise brazing. The cylinder must be preheated just as though welding were to be employed. Particular care should be used in cleaning the score. Tobin or manganese bronze can be employed, using a flux. Those shops not equipped to do regrinding will find this method of repairing an advantage. A small portable grinder is used to remove the roughness, and it can then be finished with scrapers.

WELDING ARM OF AN ALUMINUM CRANK CASE.

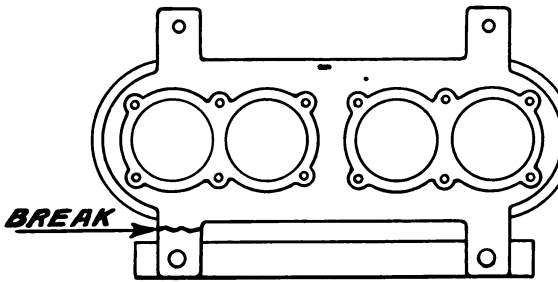



Fig. 39.

Quite frequently the arm of a case breaks. This is comparatively a simple weld. There is no necessity to take care of expansion and contraction. It is necessary to take care of alignment, and to this end a straight bar should be bolted tight to the other arm on the same side of the case, the broken arm resting on the bar and

being clamped to it, care being taken that the clamps are not drawn too tight. It will be best to start welding along the top first and then weld each side, finishing by welding on the inside, where a fillet or reinforcement can be made.

WELDING CRACK IN ALUMINUM OIL PAN.

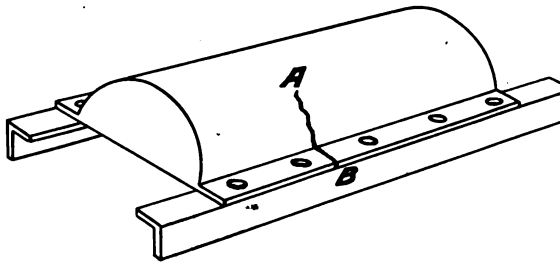



Fig. 40.

Fig. 40 shows an aluminum oil pan with a crack, AB, lined up and ready to weld. Angle irons are bolted to the case. The holes in the angle irons should be somewhat larger than the holes in the case and the bolts should not be drawn tight so that the case will have an opportunity to expand when heated, but will do so along the line and in the direction of the angle irons. The case should be pre-heated, either with charcoal, gas torch or with the welding torch. The heating should mainly be on the side opposite to the crack AB. The

degree of heat is not only somewhat difficult to determine, but is also one regarding which good welders differ. Some prefer to heat until the metal begins to sweat. In the majority of instances this is not necessary, besides one is getting dangerously near the point where the case will collapse and be ruined. Others take some salt or sawdust and sprinkle on the case, and if it chars or burns quickly, proceed to weld. The welding should start at A and proceed towards B; never in the opposite direction. Always work a weld out towards the edge. When the weld is practically completed, the one angle iron on that side should be removed and the crack touched up, a little more metal being added than necessary. This excess metal can easily be filed off.

WELDING OF A FLY-WHEEL.

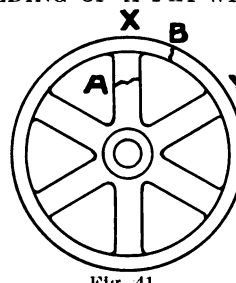



Fig. 41.

Fig. 41 represents a cast-iron fly-wheel, having a break in a spoke at A, and also

a break in the rim at B. First, let us assume that there is only one break, and it is at "A." We should have learned by this time that if we attempted to make this weld and gave no thought as to expansion and contraction, that it would be sure to break again when cooling. The proper way to take care of expansion and contraction is to heat the rim to a dull red on both sides of this broken spoke. As the rim is heated it expands outwardly, and it will be seen that the edges of the break have separated. The weld should then be made as rapidly as possible and the wheel covered up carefully and allowed to cool slowly.

Now let us suppose that we have a broken spoke, A, and a broken rim, B. This is really more simple than the one single break in the spoke at A, if we go at it in the proper way. The break at A must always be made first. Before beginning the weld, two flat iron bars should be clamped along the sides of the rim to maintain alignment. The weld at A should be started and a heavy "tack" made, then turn the wheel over and weld *one-half* the way through, when the wheel should again be turned, the "tack" melted out and the weld completed. Upon examining the crack in the rim at B, in all probability it will be seen that the part of the rim, XB,

extends a little farther out than does BY. This, of course, is due to the fact that the spoke has expanded from the heat of welding, so we should carefully heat the rim at Y until it expands and the two edges of the crack at B are even and true. Then make the weld, cover the casting and cool slowly.

### WELDING OF LARGE CYLINDERS.

In the pre-heating of large cylinders usually better results can be obtained by changing somewhat the method used on ordinary automobile cylinders. The inner wall of large stationary gas engine cylinders is usually considerably heavier than the outer or water jacket wall. The cylinder should be well swabbed with graphite and then stood upright, the lower end resting on bricks, leaving an air space of about 3 or 4 inches at the bottom. Some charcoal is then placed inside the cylinder and allowed to heat until the outer wall is fairly hot. It then should be turned over on its side and heated all over.

If gas torches are used, this is not necessary, as a small one can be placed so as to play on the inside, but not against the walls of the cylinder.

### WELDING A CRANK SHAFT.

The welding of a crank shaft should not

be attempted until one has had at least a year's experience in welding. Automobile shafts are steel with a fairly high carbon content, and, in addition, frequently contain nickel, chrome, etc. Good welders can do this class of work successfully; the fair or mediocre operator would do well to "pass them up."

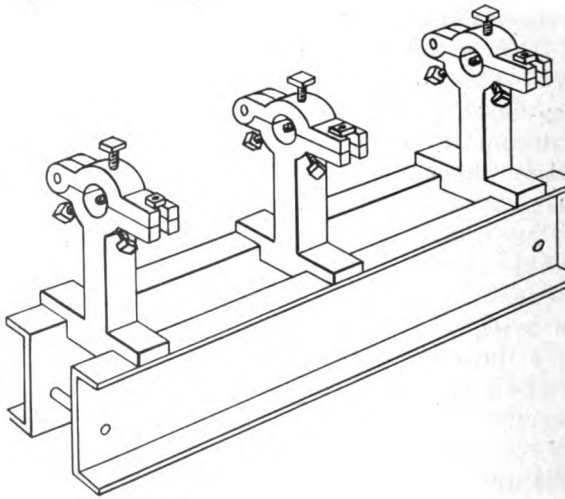


Fig. 42.

Regardless as to the quality of the weld, it will be necessary to put the shaft in a lathe and do some straightening, after the weld is completed.

Now the amount of work required in

straightening can be considerable or very little, depending upon the care exercised in lining up the shaft before welding, and the means for holding it approximately in that position. Some advocate the use of "V" blocks for this purpose. Besides being quite expensive, they are of very little value, and a straight piece of heavy angle iron will answer as well.

A simple and inexpensive means for holding shafts is shown in Fig. 42. It is copied very much after the steady rest on a lathe. The shaft is lined up by means of set screws and a straight edge and a surface gauge are used to determine when it is correct. The shaft is then tacked and again tried to see if it is true and the set screws are tightened so that the shaft can be easily turned. The weld is then made.

When finished and while hot, it is again tested, and if "off" it is an easy matter to straighten by tightening up on one set screw while loosening the opposite one.

A great many shafts have been welded on a device of this kind and very little machining was necessary afterwards.

### WELDING OF PARTITIONS IN OIL TANK WAGONS.

Most of the oil concerns who deliver oil in tank wagons, when ordering new

tanks are specifying that they shall be welded throughout. These tanks carry gasoline, kerosene and other grades of oil, so that this calls for several compartments, necessitating partitions. As a leak in a partition might result seriously, they usually specify that there must be provided two partitions, instead of one. These partitions are made from flat stock and are

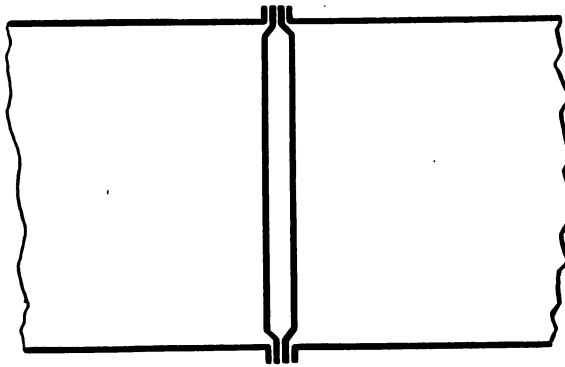


Fig. 43.

dished very much like a pie pan. This is practically all that is necessary, to take care of expansion and contraction. The edges at the ends of two tanks are flanged, the two dished partitions are set in position (see Fig. 43), and the four edges are tacked at four or five points. The four edges are then welded all the way around.

## WELDING HORSE.

Figure 44 shows a welding horse, with aluminum case in position being welded. This horse is so simple to make and yet is so great a convenience in a custom repair shop, that a description of it and its uses would seem advisable.

In the majority of shops the custom has been for the welder to use a helper when working on aluminum cases, especially if they were of rather large size. The duties of the helper were to turn the casting from time to time, keeping the portion that was actually being welded in a horizontal position. Sometimes the helper was dispensed with and the welder did his own turning, supporting the casting, from time to time, by means of brick or other devices. At times this places a considerable strain on the casting, causing it in some instances to crack elsewhere than in the weld. Often the supporting bricks, having been placed hurriedly in position, would slip and allow the case to drop, with more or less resulting damage. This welding horse eliminates all of this. The case is simply bolted to the frame of the horse. The frame and the attached case can revolve on the supporting shaft by loosening a set screw and can be instantly fixed in

any desired position by simply tightening the set screw. This horse is made as follows:

The legs are made of ordinary standard ¾" pipe and are cut about 32 inches long. A piece of 1¼-inch pipe about six inches

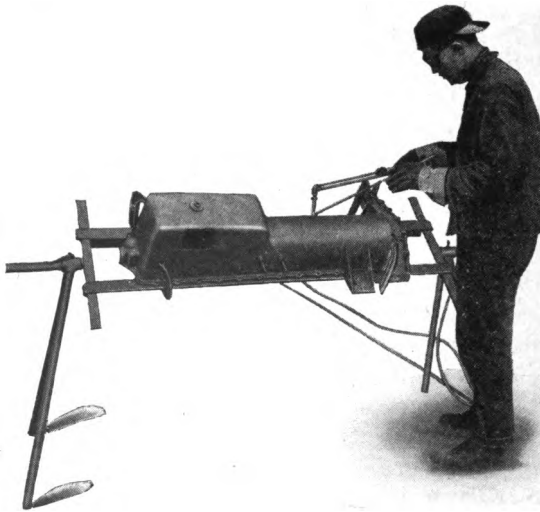


Fig. 44.

Welding Horse for Holding Aluminum Cases.

long is butted against two legs and welded. The legs should be positioned to incline inward somewhat. On the top of the short 1¼-inch pipe build up a lug about ½-inch high. Then drill about a ⅜-inch or ½-inch

hole and tap. This is to receive a set screw. Then get two straight pieces of angle iron about 4 or 5 feet long. This angle iron should be about 2″x2″x¼″. At each end cut out a small square from one flange about 2″x2″.

This cut should be made on the same flange for both pieces of angle iron. Weld on the under side of the uncut portion a piece of bar stock formed in a "U" shape. This will form a slot through which passes a flat bar forming the end. On the side of the "U" shaped piece build up a lug, drill and tap for a set screw.

For the ends, get two pieces of flat stock about 1½″x½″, and each two feet long. In the center of each and at right angle weld a piece of 1″ pipe about 8″ long. These two pieces of pipe will form the shaft for the welding horse and the bearings will be the two pieces of 1½″ pipe welded onto the legs. The two pieces of angle iron which form the sides can be moved in or out on the two flat bars forming the ends, and thereby adjusted to the width of the case. Ordinary clamps are used to fasten the case to the angle irons.

## WELDING OF DIES.

Dies are, of course, made from high carbon steel. As we have previously stated,

high carbon steels are difficult to weld; however, very satisfactory welding is done on this class of work. Ordinary Norway iron can be used as a filler, but it must be remembered that it will be impossible to temper the metal in the weld on account of its low carbon content. Some concerns, notably shoe factories, use a great many small cutting dies. They are very thin, and the breakage is considerable. In welding, Norway was used, but it was exceedingly difficult to prevent blow-holes from forming near and at the thin cutting edge. By experimenting, a high carbon filler rod was found which eliminated this trouble and also gave a harder cutting edge. Those interested sufficiently to write to the author will be gladly given the name of this steel.

### WELDING OF HIGH CARBON TOOL STEEL TO LOW CARBON.

The exceedingly high price of high carbon steel during the past year has caused many concerns to interest themselves in some method that would show an economy in the use of this material, with the result that a great many are now using for their cutting tools a small piece of high carbon to which has been welded a longer piece of low carbon. The same thing is done with high speed and tool steel. Very little, if

any, bevel is made on the high carbon piece, whereas a very long bevel is made on the low carbon bar. The secret as to successful welding on this class of work is in preheating both pieces until they are a cherry red all over and then welding fast, using as a filler either vanadium or nickel steel, although Norway can be used.

### WELDING OF MANGANESE STEEL.

The welding of manganese steel is not a success. While the metal can be run together, the weld will be found to be porous, brittle, and, of course, possessing little strength. It is extremely doubtful if it ever will be welded successfully with the flame. The government specifications for this steel call for a manganese content of not less than 11% nor more than 13%. Manganese has a great affinity for oxygen, with the result that when the steel is melted a considerable amount of the manganese burns out, leaving less than 11% behind. Attempts to put manganese back into the casting by using a filler rod high in manganese have not proven a success, as it would be luck if only enough were added to come within the narrow range of from 11% to 13%. Manganese steel is used for switch frogs, safes, ore crushing rolls, dredge dippers, etc.

## THE USE OF ALUMINUM SOLDER.

Those doing custom welding should be capable of soldering aluminum. It is not difficult, and there are occasions when its use is desirable. It must be remembered that a soldered joint will not have the strength of a weld, claims of some manufacturers of aluminum solder to the contrary notwithstanding. For that reason soldering should not be resorted to where it is necessary to secure in the joint strength equal to other parts of the casting. A small crack in the bottom of an aluminum oil pan is an instance in which soldering can be successfully done. Here there is no strain and little strength required. The important consideration is that it shall be oil tight.

The crack is beveled out to an angle of at least 90 degrees. It is of the utmost importance that it shall be clean and bright. A tip of small size should be used in the welding torch and only the brush flame or envelope brought in contact with the metal. While the crack is being heated a wire hand brush should be used vigorously until the sides are as bright as a new silver dollar. Any good aluminum solder can be used. There are quite a number on the market. As soon as the crack is clean and fairly warm, rub the

end of the solder in the crack and on the side and a small amount will adhere. The wire brush must be then used again, rubbing the solder in until every crack, crevice and part of the beveled sides are coated with the solder. While this is being done the torch is being played over the crack and by this time the casting should be hot enough to melt the solder when it is rubbed against the crack. Melt enough to fill up the crack and extend over the sides a little and use an old hickory hammer handle that has been flattened on one side to press the solder into shape. When this has been done, be careful not to move the casting until it has cooled sufficiently to allow the solder to set.

### USE OF OXYGEN FOR REMOVING CARBON.

The use of oxygen for the removal of carbon in cylinders is now very generally employed. The process is one of simple combustion, the carbon burning to a gas in the presence of pure oxygen. This burning is usually attended by a considerable pyrotechnic effect, so that the onlooker is apt to think that an exceedingly high temperature is obtained which might injure the cylinder. Such is not the case. The temperature is somewhat below that prevailing in the combustion chamber when

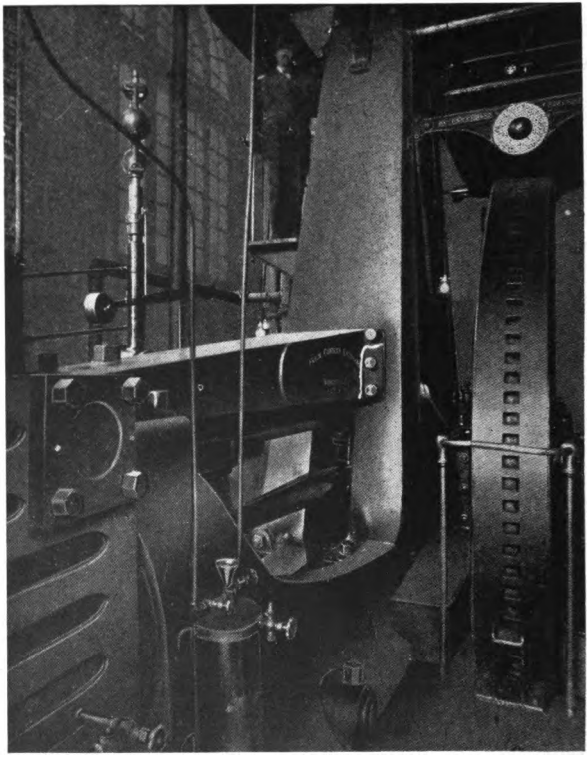


Fig. 45.

This cut shows a large casting on an ice machine that was welded. A part of the flange was broken off and the crack extended up into the body of the casting. It was necessary to dismantle, but presented no serious difficulty in welding aside from the fact that the turning of a casting of its size in order to get at every part of the crack was somewhat tedious.

The entire end of the casting was pre-heated.

the engine is running so that no trouble can come from that score. An analysis of the carbon in cylinders discloses that it contains road dust or silica. The oxygen will not remove this.

Fig. 46.

This cut shows a large copper still with longitudinal seams and connections welded. This still was 4½ feet in diameter by about 6 feet high. The metal did not exceed $\frac{3}{16}$ of an inch in thickness, and yet on account of the conductivity of the copper it was found necessary to build a coke fire on the inside and cover the outside with asbestos in order to hold the heat.

To those not familiar with the process it is necessary to impress upon them that oxygen only is used. Acetylene plays no part and is not used, the carbon in the cylinder acting as the only fuel. The equip-

ment necessary is a tank of oxygen, a regulator which reduces the pressure, about 12 feet of hose and either a special carbon torch or a special tip which is attached to the welding torch. The operation is prepared for as follows:

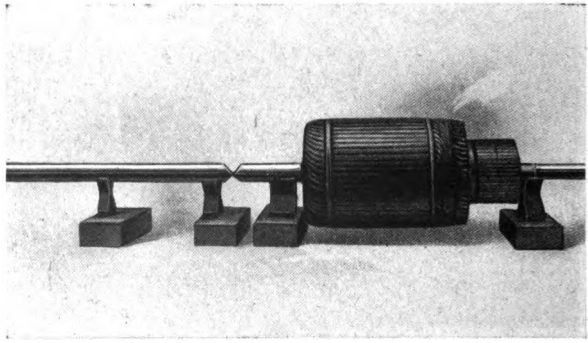


Fig. 47.

This cut shows an armature with shaft beveled and lined up preparatory to welding. In this case the weld was far enough removed from the armature as to not endanger burning the insulation. Where the weld is closer to the armature it is necessary to cover that end with wet asbestos. As the weld progresses, an assistant can from time to time slowly pour water on the asbestos.

The gasoline tank is cut off and the motor started and allowed to run until it stops of its own accord. This indicates that all of the gasoline in the carburetor has been used up, which is one of the things desired. It is important that no gasoline

be allowed to remain in the line from the tank to the carburetor, and if there is a vacuum feed, it should be drained. Remove either the valve caps or the spark plug on the first cylinder and turn the engine over until this cylinder is on compression. This means that the piston is at

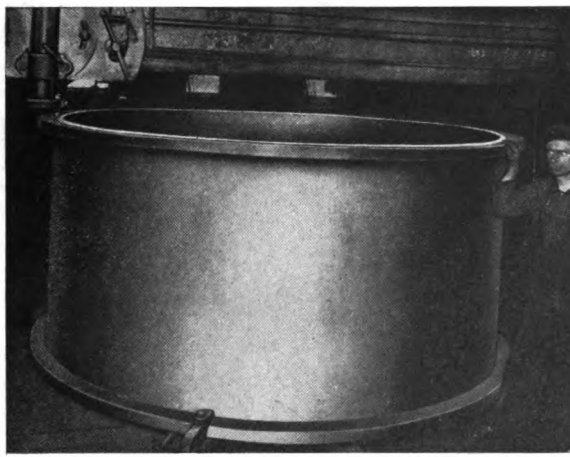


Fig. 48.

This is a large cast-iron cylinder 14 feet in diameter and weighing 30,000 pounds. A part of the flange was broken off and in addition there were a great many blow-holes in the unbroken part.

On account of the size, and the fact that the welding was on an edge, no attempt was made to pre-heat. The broken parts were welded back and the blow-holes filled up. It was impossible to prevent chilling of the metal and in facing off, an emery wheel was found necessary.

The welded casting has now been in service several years, giving entire satisfaction.

the top of its stroke and the valves closed. The oxygen tank should then be opened slowly and the regulator set at about 15 pounds. Drop a lighted match into the valve chamber, insert the copper tubing and turn on the oxygen. If the flame is

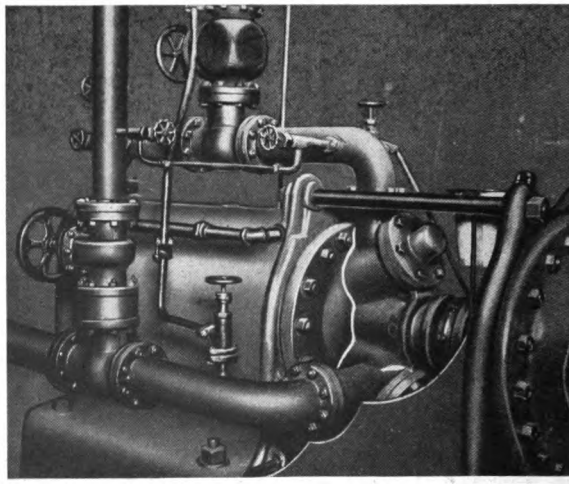


**Fig. 49.**

This shows the head of a large ammonia compressor which was badly broken and successfully welded. Not only was it necessary to stand high pressure, but it must also be ammonia tight and any one familiar with the penetrating quality of that gas realizes that the weld had to be free from blow-holes. The metal was about 3 inches thick and the length of the break 36 inches.

Fortunately, with the exception of about 6 inches, the welding was all in one position. The crack was carefully chamfered and lined up and then pre-heated until red all over.

considerable, reduce the amount of oxygen pressure.

If the carbon does not seem to burn well and increasing the oxygen pressure does not help, inject just a few drops of oil, kerosene or lubricating.

Compressed air or a small hand bellows should be used to blow out particles of road dust or grit that remains, and the valve seats should be cleaned with a swab.

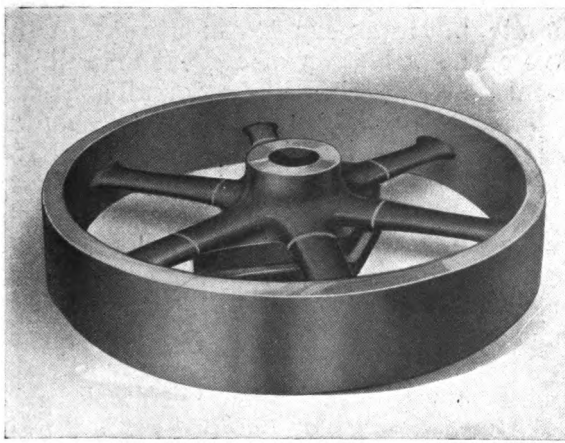


Fig. 50.

This shows a large fly-wheel which had all six spokes broken, and which was successfully welded.

In this case the entire wheel, rim, hub and spokes was pre-heated and all but a very little welding was done from one side. In this case it was impossible to keep the bore in the hub true, so that the bore was enlarged and a bushing inserted.

The remaining cylinders are treated in like manner.

It is good policy to have near at hand a fire extinguisher, as the proximity of grease and oils to the flying sparks must be considered.

### COST-CARD.

Some kind of a time or cost card should be kept where job or repair welding is done. By doing so you will not only have a record of the operation in the event of a dispute, but in a very few months you will have on file a history of a great many different jobs, which will be found a great assistance in determining a price should the customer desire it. Few custom welding shops properly take into account what is known as overhead expense. This includes rent, telephones, advertising, postage, bad accounts, depreciation of equipment, failure of welds, etc. At least 100% should be added to the actual labor, gas and material cost to cover the overhead. Unless this is done one will not go ahead.

If the owner of the shop does his own welding, he should charge this up at the same price he would have to pay did he employ a welder.

A cost card for repair welding is shown on page 177.

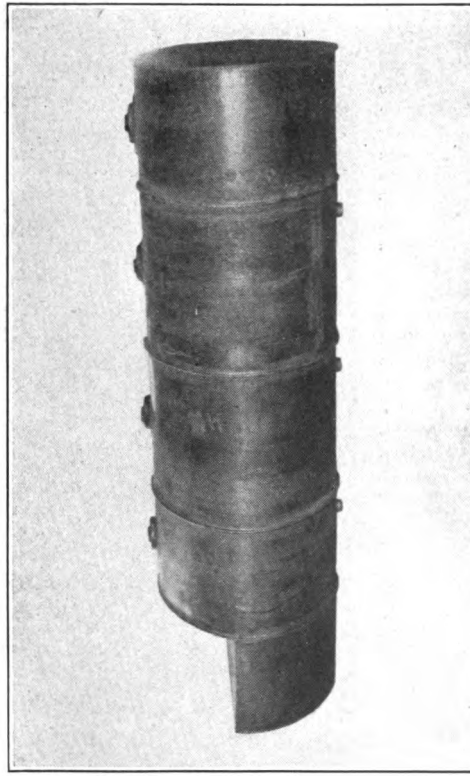


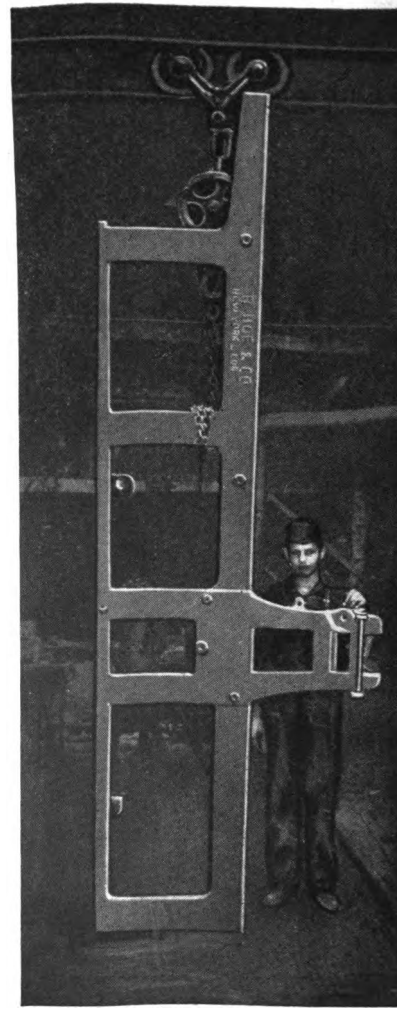
Fig. 51.

This is a cut taken of a compartment oil tank used on a delivery wagon. The manner in which the partitions are formed and welded in is described elsewhere, as is also the welding of the filling and drainage plugs.

The manufacture of these tanks presents no serious difficulties.

Fig. 52.

This shows part of the frame of a large Hoe printing press. This was broken at the white line near the man's hand. The metal was 4 x 5 in. A pre-heating torch was directed on the break but in such a position that the main casting instead of the broken-off part received most of the heat. The welding was completed in only a few hours enabling the customer to print his paper without the loss of a single issue.



| | | | | |
|---|---|---|---|---|
| Date | June 1st, 1916 | | Shop Ticket No. 50 | |
| Article | Single Cylinder | | | |
| Kind of Weld | 5 inch crack in water jacket | | | |
| Pressure Oxy. Start | 1750 lbs. | | in 100 cu. ft. tank | |
| Pressure Oxy. Finish | 1400 lbs. | | | |
| | 350 lbs. | | | |
| | GAS USED. | | | |
| Cu. Ft. Oxygen | Used 20 | @ | 2c | $ .40 |
| Cu. Ft. Acetylene | Used 20 | @ | 3c | .60 |
| | LABOR. | | | |
| Preparing—Hrs. | Min. 30 | @ | $ .80 | .40 |
| Welding —Hrs. | Min. 30 | @ | 1.00 | .50 |
| Finishing—Hrs. | 1 Min. | @ | .80 | .80 |
| | MATERIAL. | | | |
| Rods | | | | |
| —Lbs. Steel | | @ | | |
| 1 —Lbs. Cast Iron | | @ | .15 | .15 |
| —Lbs. Bronze | | @ | | |
| —Lbs. Aluminum | | @ | | |
| Flux | | | | .05 |
| —Lbs. Charcoal | | | | |
| Pre-Heating Torch ½ Hour | | | | .10 |
| TOTAL | | | | $3.00 |

RECEIPT TICKET.

Whether the broken casting is brought to the welding shop by a firm using their own dray ticket or by an individual, the welding shop's own receipt ticket should be given. It is important that this receipt ticket have printed at the top the conditions under which the casting is accepted. A sample ticket is shown herewith.

We guarantee our ordinary class of work, by refunding the amount paid for the work, if it should break again in the line of the weld within 30 days

from date of delivery to owners, or we will reweld again free of charge, parts to be submitted to us, transportation prepaid for our decision. If we cannot succeed in making a satisfactory job, we do not make any charge for the work; our responsibility ends here.

We are not responsible for the parts left in our charge after 30 days.

We accept parts only as being of scrap value, and are not responsible for delays of any kind.

All work is received subject to above conditions and guarantee.

---

John Jones Welding Co.,
No. 250 Order No. 52
St. Louis, January 10, 1916.
Received from Smith Auto Company
2826 Locust Street
1 Aluminum Case
To be done 1/12/16 Price $15.00
Taken out by Sam Johnson
Date 1/12/16

These tickets should be made in duplicate, one being given and one retained by the welding shop, and upon this latter one the customer's receipt is obtained when the casting goes out.

## TABLES AND USEFUL INFORMATION.

### WEIGHTS OF VARIOUS METALS.

| | Ave. weight of 1 cu. ft. in pounds | Ave. weight of 1 cu. in. in pounds |
|---|---|---|
| Grey Iron | 450 | .2606 |
| Wrought Iron | 480 | .278 |
| Mercury | 849 | .491 |
| Silver | 655 | .579 |
| Aluminum | 162 | .0932 |
| Cast Copper | 542 | .313 |
| Rolled Copper | 555 | .321 |
| Steel | 490 | .283 |
| Tin | 459 | .265 |
| Zinc | 427.5 | .252 |

## METRIC AND ENGLISH SYSTEMS.

| | | | |
|---|---|---|---|
| 1 pound | equivalent to | .4536 | Kilograms |
| 1 inch | equivalent to | 25.4 | Millimeters |
| 1 foot | equivalent to | .3048 | Meters |
| 1 mile | equivalent to | 1.6094 | Kilometers |
| 1 sq. inch | equivalent to | 645.2 | Sq. Millimeters |
| 1 sq. foot | equivalent to | .09291 | Sq. Meters |
| 1 cubic inch | equivalent to | 16.39 | Cu. Centimeters |
| 1 cubic foot | equivalent to | .02832 | Cu. Meters |
| 1 quart | equivalent to | 1.101 | Litres |
| 1 Kilogram | equivalent to | 2.2047 | Pounds |
| 1 Millimeter | equivalent to | .0394 | Inches |
| 1 metre | equivalent to | 3.2807 | Feet |
| 1 Kilometer | equivalent to | .6213 | Miles |
| 1 Sq. Millimeter | equivalent to | .00155 | Sq. Inch |
| 1 Sq. Metre | equivalent to | 10.763 | Sq. Feet |
| 1 Cu. Centimeter | equivalent to | .0610 | Cubic Inch |
| 1 Cu. Metre | equivalent to | 35.3105 | Cubic Feet |
| 1 Litre | equivalent to | 61.017 | Cubic Inches |

## TABLE SHOWING THE ORDER OF

| *Malleability.* | *Ductility.* | *Tenacity.* | *Infusibility.* |
|---|---|---|---|
| Gold | Platinum | Iron | Platinum |
| Silver | Silver | Copper | Iron |
| Aluminum | Iron | Aluminum | Copper |
| Copper | Copper | Platinum | Gold |
| Tin | Gold | Silver | Silver |
| Lead | Aluminum | Zinc | Aluminum |
| Zinc | Zinc | Gold | Zinc |
| Platinum | Tin | Tin | Lead |
| Iron | Lead | Lead | Tin |

To transform temperature readings from Centigrade to Fahrenheit double the centigrade number, diminish it by one-tenth of itself and add 32. As an example: 100 degrees Centigrade is equivalent to 212 degrees Fahrenheit. Doubling 100 gives us 200, deducting one-tenth leaves 180 and adding 32 we have 212.

For changing Fahrenheit into Centigrade the rule is, subtract 32, increase the remainder by one-ninth of itself and take one-half.

To find diameter of a circle multiply circumference by .31831.

To find circumference of a circle multiply diameter by 3.1416.

To find area of a circle multiply square of diameter by .7854.

To find surface of a ball multiply square of diameter by 3.1416.

To find side of an equal square multiply diameter by .8862.

To find cubic inches in a ball multiply cube of diameter by .5236.

Doubling the diameter of a pipe increases its capacity four times.

Double riveting is from 16 to 20 per cent. stronger than single.

A gallon of water (U. S. Standard) weighs 8⅓ pounds and contains 231 cubic inches.

A cubic foot of water contains 7½ gallons, 1728 cubic inches, and weighs 62½ pounds.

To sharpen dull files lay them in dilute sulphuric acid until they are eaten deep enough.

A horse power is equivalent to raising 33,000 pounds one foot per minute, or 550 pounds one foot per second.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434.

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